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INTRODUCTION

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Since 1978 the Merced County Health Department has detected nitrate levels in ground water of the Hilmar area which exceed the drinking water standard of 10 milligrams per liter (mg/l) $\text{NO}_3\text{-N}$. As a result of these excessive nitrate levels some residents are currently using bottled water for drinking instead of their own well water. A few dairymen have complained that their cows are aborting at a higher than normal rate. A local dairy inspector attributes this to excessive nitrates. This study was conducted to determine the extent and most likely sources of the high nitrate levels and to make recommendations to reduce the problem.

Since Hilmar is an intensively farmed area, other ground water problems related to agriculture were also looked at. These include possible problems with high levels of salts and pesticides.

Area of Investigation

The study area consists of an approximately 3 mile square centered around the City of Hilmar (see Figure 1). It includes a small portion of southern Stanislaus County and a larger portion of northern Merced County. Some portions of Turlock and Delhi are included to the north and east, respectively.

Agriculture is the predominant land use, with corn, oats, almonds, and alfalfa making up approximately 82 percent of the total cropland. There is also a high

density of confined animal facilities, mostly dairies with some feedlots and poultry operations present as well.

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Ground water is the major source of drinking water in the area. Residents in the City of Hilmar receive their water from a large municipal well. Outside the city limits, most residents use water from private wells for drinking. As mentioned, some people are drinking bottled water. Water from the Turlock Irrigation District (TID) canals, which brings water from the Tuolumne River, is the main source of irrigation water. TID uses drainage wells to keep the ground water level at least 6 feet below the ground surface. Water pumped from the drainage wells is discharged into the TID irrigation canals which then transport the water to the San Joaquin River or to the Merced River.

Most of the Hilmar study area is served by septic tank systems. The City of Hilmar itself is on a sewer system (see Figure 2). The sewage treatment plant is located southeast of the city and discharges its wastes to a 20 acre site located near the treatment plant.

Scope of the Investigation

The initial work involved locating known and potentially high nitrate areas. Water quality analyses from the Merced County Health Department were looked at to identify areas known to have shown high nitrates in the past as well as at the present. Land use maps and aerial photos were used to locate potentially high nitrate areas such as dairies, feedlots, poultry operations, golf courses, and crops which receive large applications of fertilizers (see Figure 2).

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The initial work also included a review of existing geologic and hydrogeologic literature to determine the extent and character of the water bearing zones. Depth and thickness of the upper unconfined and lower confined aquifers, water levels, and direction of ground water movement were determined based on these reports.

A ground water sampling program was conducted in June of 1986 in which domestic, irrigation, dairy, and drainage wells were chosen for water quality sampling based on the kind of information available on the well and the location of the well. An effort was made to sample only those wells which had well logs on file at the Department of Water Resources (DWR) or for which well depth and casing diameter information was available. This information makes it possible to determine which aquifer the well is drawing water from and to determine the pumping time needed to obtain a water sample representative of the ground water. Some wells of unknown or uncertain depth were sampled because they were the only ones available in an area of interest, an owner requested an analysis, or because the Merced County Health Department had previously found high nitrate levels there.

Where possible, at least one well was sampled in each section of the study area. Most wells sampled were located near a dairy operation, while some were chosen outside the influence of dairies or other suspected sources of nitrate to obtain a background level of nitrates. To study the effects of fertilizers a few wells were sampled down ground water gradient from the Turlock Country Club Golf Course

and in orchards where fertilizer application rates are typically higher than normal.

All wells were sampled for nitrates, while only those wells with known depths were sampled for minerals also. Wells which are located within or down ground water gradient from orchards were also sampled for pesticides. Those wells which showed nitrate levels above the drinking water standard in June were resampled for nitrates only in October of 1986 to verify the initial results. Water from 14 wells was analyzed for nutrients in an effort to distinguish animal wastes as a source of nitrates from commercial fertilizers.

Water from 2 irrigation canals and 2 dairy ponds was analyzed for nitrates and minerals. A complete nutrient analyses was also performed on one of each of these 2 surface waters.

An estimate of the total nitrogen and salt loading rates was made for the entire study area. The application of animal wastes, commercial fertilizers, and irrigation water to cropland, the use of septic tanks, the application of treated sewage water to land, and nitrogen fixation by leguminous plants were all considered in estimating the loading rates.

A survey of animal waste management practices by individual dairies and poultry operations was conducted to determine loading rates by these operations. Information on recommended fertilizer application rates and fertilizer types for specific crops was obtained from the University of California Cooperative Extension Office in Merced County and the Stanislaus Farm Supply. This

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information was used with crop acreages determined from the Department of Water Resources 1980 land use map to determine loading rates due to the use of commercial fertilizers.

Nitrate Toxicity

Nitrates are toxic to both humans and animals. In humans, toxicity is generally associated with infants less than 3 months old, and rarely in adults.

Nitrite, the reduced form of nitrate, causes the health problems associated with nitrates. Nitrate can be reduced to nitrite in the intestines of ruminant animals and infant humans and monogastrics (pigs and chickens). In older, healthy adults fairly large amounts of nitrate can be ingested and excreted in the urine with little effect. However, infants do not have sufficient amounts of acid in their digestive system to prevent the growth of bacteria which can change nitrates into toxic nitrites. The nitrite is then adsorbed into the bloodstream and reacts with hemoglobin in the blood, to form methoglobin. The formation of methoglobin interferes with hemoglobin's ability to transport oxygen through the body. High levels of methoglobin can significantly decrease the amount of oxygen which is carried by the blood, resulting in signs of suffocation, or methoglobinemia. Symptoms of methoglobinemia in human infants include a bluish color to the skin, vomiting, and diarrhea.

Ruminant animals such as cows and sheep and infant pigs and chickens have bacteria in their digestive systems which can convert nitrate to nitrite. The digestive systems of adult horses also have the ability to produce nitrites.

Livestock may consume nitrates from their feed as well as their water and may develop methoglobinemia. Symptoms of nitrate poisoning in animals may include depression, weakness, rapid pulse, labored breathing, dark mucous membranes, or convulsive movement of the legs. Cows which are not fatally poisoned may abort dead calves.

Since 1945, approximately 2,000 cases of infant methoglobinemia have been reported from North America and Europe. Only about 7 or 8 percent of these cases have been fatal (Hergert, 1986). The recent death of a 2-month old infant in South Dakota has been attributed to excessive nitrates in a rural well (Ground Water Monitor, 1986). Acute nitrate poisoning in cattle has been recognized for some time.

Because of nitrate toxicity, a recommended drinking water standard of 10 mg/l $\text{NO}_3\text{-N}$ (45 mg/l NO_3) was made part of the 1962 U.S. Drinking Water Standards and is also part of the State of California's Basin Plan. Guidelines established by the National Academy of Sciences for livestock drinking water recommend an upper limit of 100 mg/l $\text{NO}_3\text{-N}+\text{NO}_2\text{-N}$ to prevent livestock poisoning.

GEOLOGY

Regional Geology

The San Joaquin Valley is a topographic and structural trough which has received a thick accumulation of sediments from the Sierra Nevada on the east and the Coast Ranges on the west. The east side of the valley, bounded by the Sierra

Nevada fault block, is gently dipping to horizontal and lies unconformably over the granite basement rocks of the Sierra Nevada. The west side of the valley dips steeply at its extreme western boundary along the base of the folded and faulted Coast Ranges, where it lies unconformably over ultramafic intrusives and the Franciscan Formation. The axis of the trough is asymmetric and close to the western margin of the valley, lying to the west of the present day San Joaquin River. The San Joaquin River has migrated eastward since the Pleistocene Age, thus Sierran deposits interfinger with Coast Range deposits in the subsurface west of the present day San Joaquin River.

Geomorphic Units

The Hilmar study area includes 3 geomorphic units of Page & Balding (see Figure 3).

The older alluvium unit comprises all but the southern edge and the southwestern portion of the study area. It is nearly flat, sloping about 6 feet per mile to the west or southwest. Relief is as much as 36 feet from the east side of the area to the west side. The alluvium is dissected at its southern boundary by the Merced River.

Younger alluvium occurs as a narrow band along the Merced River, sloping less than 1 foot per mile.

Flood basin deposits occur in the southwest portion of the area. These deposits flank the San Joaquin River.

Geologic Units and Their Water-Bearing Characteristics

The rocks that make up the 2 aquifers supplying water to the Hilmar area consist of unconsolidated deposits of Tertiary and Quaternary Age. Consolidated Miocene and Pliocene rocks of the Mehrten Formation which lie immediately below these deposits will be discussed briefly also. See Table 1 for a generalized geologic section of the Hilmar area and the water-bearing characteristics of the different geologic formations.

Consolidated Rock

Mehrten Formation

Miocene and Pliocene deposits of the Mehrten Formation lie conformably over the Valley Springs Formation and consist of andesitic fluviatile deposits of sandstone, breccia, conglomerate, turf, siltstone, and claystone. The Mehrten outcrops in a northwest-southeast trending belt east of the Hilmar study area. Its thickness in the study area is unknown, but it thickens to a maximum of 1,200 feet under the valley center (CDMG, 1962), its upper surface occurring at about 600 feet below sea level in the northeast portion of the study area to about 1,000 feet below sea level in the southwest portion of the study area (Davis and Hall, 1959).

The Mehrten Formation is an important aquifer east of the study area where it occurs at shallower depths. None of the wells sampled in this study penetrate this formation.

Unconsolidated Deposits

Continental Deposits

Pliocene and Pleistocene continental deposits lie unconformably over the erosional surface of the Mehrten Formation to the east of the study area. In the study area the deposits range in thickness from about 300 to 400 feet, the surface of the formation occurring between about 100 and 300 feet below sea level (Page and Balding, 1973). The deposits occur in a northwest-southeast trending belt east of the Hilmar area, where they then dip gently to the southwest beneath the overlying older alluvium. The sediments consist of poorly sorted gravel; sand, silt, and clay and are generally finer grained than the older alluvium. Surface outcrops show the continental deposits to be lenticular and commonly cross-bedded, the texture and composition suggesting it was deposited as a series of alluvial fans originating from the Sierra Nevada.

Maximum well yields are 281 cfm and maximum specific capacities are 3 ft²/min (Page and Balding, 1973).

Lacustrine and Marsh Deposits

Pleistocene lacustrine and marsh deposits form a continuous confining layer within the older alluvium. These deposits range in thickness from about 40 to 60 feet in the study area, the base of the deposit occurring between 50 and 200 feet below sea level (Page and Balding, 1973). These deposits consist of gray and blue silt, silty clay, and clay. The clay is called "blue clay" by local drillers and is known as the E-clay, having been correlated with the E-clay of Croft in the San Joaquin Valley south of Fresno and to the diatomaceous clay of Davis and others. In most places the E-clay is probably equivalent to the Pleistocene Corcoran Clay Member of the Tulare Formation.

There are other silt and clay beds above and below the E-clay, but none are continuous over a large area. Thus they are only of local importance to ground water confinement.

Older Alluvium

Older alluvium of Pleistocene and Holocene Age lies over the continental deposits. This deposit surfaces over the majority of the study area, extending from the ground surface to between 100 and 300 feet below the ground surface (Page and Balding, 1973). It consists of intercolated beds of silt, clay, sand, gravel, and some hardpan. These deposits are similar to the continental deposits in that they are lenticular and commonly cross-bedded, also having been deposited as alluvial fans by streams draining the Sierra Nevada. The older alluvium is coarser grained than the underlying deposits in some places.

Most of the wells sampled in this study draw water from the older alluvium. In T6S, R10E, the township covering the majority of the study area, the mean yield from the older alluvium was determined by Page and Balding to be about 180 cfm, ranging from 80 to 308 cfm. In the northern two-thirds of the study area, the specific capacity is usually larger than 5.3 ft²/min. Specific capacities in the southern third of the study area are less than 5.3 ft²/min. Wells perforated below the E-clay generally show a lower mean specific capacity than those perforated above the E-clay.

Younger Alluvium

Younger alluvium, of Holocene Age, occurs as a narrow band along the Merced River. It is up to 100 feet thick and consists of fine sand, sand, gravel, and some silt and clay with little or no hardpan. It is interbedded with floodbasin deposits in the western half of its occurrence in this area. The younger alluvium is not completely saturated in most places and thus would probably only show moderate yields to wells.

Flood-Basin Deposits

Flood-basin deposits, of Holocene Age, crop out in the southwestern portion of the study area and consist of intercolated lenses of bluish-gray, brown, and reddish-brown fine sand, silt, and clay. These deposits are up to 100 feet thick and are interbedded with the younger alluvium and probably the older alluvium.

The flood basin deposits are relatively impermeable and thus would probably yield only small amounts of water to wells.

Geologic Structure

The geologic structure is that of a southwestward dipping homocline. This reflects the back slope of the southwestward-tilting fault block of the Sierra Nevada. The overlying, fresh-water bearing rocks also dip southwestward, resulting in the general movement of groundwater to the west and southwest. No faults are known to have influenced the movement of ground water in the sedimentary rocks, although faulting has occurred in the basement complex.

HYDROLOGY

Occurrence of Ground Water

Only 2 of the 3 aquifers in the area were sampled for water quality. These 2 are the upper unconfined aquifer and the lower confined aquifer. The third aquifer not tested occurs in consolidated rock below the confined aquifer.

Unconfined Aquifer

The unconfined aquifer occurs above the E-clay in the unconsolidated older alluvium, younger alluvium, and flood-basin deposits. It extends from about 5 to 26 feet below the ground surface to the top of the E-clay with a maximum thickness of about 215 feet in the Hilmar study area.

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Due to the presence of local clay lenses semiconfined conditions probably exist, resulting in anomalous drawdowns during heavy pumping. Such water levels probably return to the normal water-table conditions during nonpumping.

Confined Aquifer

The confined aquifer occurs below the E-clay in the unconsolidated older alluvium and continental deposits. It extends from the base of the E-clay to the top of the Mehrten Formation. However, in terms of use, the base is considered to be the base of the fresh water, fresh water being defined as water having a specific conductance of less than 3,000 micromhos per centimeter. The head in the confined aquifer is less than in the upper unconfined aquifer. Logs of a few wells perforated in the confined aquifer and sealed off from the upper aquifer show the piezometric surface to be about 24-38 feet below the surface.

Aquifer in Consolidated Rocks

Water in the consolidated rocks occurs as perched and confined water. Aquifers in the consolidated rocks have not been defined due to insufficient data. They are thus grouped here as the aquifer in consolidated rocks.

Movement of Ground Water

The direction of the regional ground water flow in the unconfined aquifer is indicated by the ground water contour map developed by the Department of Water

Resources. Both the Spring and Fall 1984 maps, the latest ones available, indicate the flow is generally to the west and southwest towards the San Joaquin River and towards the Merced River in the southern portion of the study area (see Figures 4 and 5). The direction of regional ground water flow in the confined aquifer is probably also to the west and southwest, toward the valley trough. Pumping depressions cause temporary local variations in the direction of ground water flow, both in the unconfined and confined aquifers.

Since the confined aquifer has a lower head than the overlying unconfined aquifer, water from the unconfined aquifer moves vertically down to the confined aquifer through the E-clay, particularly through the annular space of improperly sealed wells which penetrate the confined aquifer.

Water-Level Fluctuations

Since the Hilmar area relies heavily on surface water supplies for irrigation high water levels in the unconfined aquifer result, making it necessary to use drainage wells to lower the water table. These drainage wells are turned on when the water level is less than 6 feet below ground surface, discharging the water into one of the canals which carry water from the Tuolumne River towards the San Joaquin River. Natural ground water level fluctuations range from 5 to 26 feet below ground surface.

As mentioned above, some well logs indicate that the piezometric surface of the confined aquifer can vary from 24 to 38 feet below ground surface.

Sampling and Analytical Methods

Water samples were collected after purging 3 casing volumes of water from the well to obtain a representative sample of the aquifer water. In addition, the electrical conductivity (EC) and temperature of the water were monitored during pumping to be sure that both had stabilized before a sample was collected.

Plastic containers rinsed in hydrochloric acid were used for collection of samples to be analyzed for nitrates, minerals, and nutrients. Half-gallon containers were used for samples collected for mineral and nitrate analyses. Samples to be analyzed for nutrients were collected in one-gallon containers. All containers were rinsed 3 times with the water to be sampled before the actual sample was collected.

One liter amber glass bottles were used for collection of samples to be analyzed for pesticides. Samples collected for DBCP analyses were stored in VOA glass vials. Both the VOA and amber glass bottles were rinsed 3 times with the water to be sampled before filling the bottle completely, being careful to leave no air bubbles in the sample bottle.

All water samples were immediately put on ice and cooled to 4°C. The samples were maintained at 4°C until delivery to the laboratory. All samples were hand delivered to the lab on the day of collection or the following day. In addition, samples collected for nitrate and nutrient analyses were preserved within 12

hours of collection with sulfuric acid to bring the pH to 2 or less. Laboratory analyses for nitrates and nutrients were performed within 28 days of sample collection.

Anlab Analytical Laboratories in Sacramento performed the nitrate, mineral, and nutrient analyses. The majority of the pesticide analyses were performed by California Analytical Laboratories, Inc. of Sacramento. California Water Labs, Inc. of Modesto also performed some of the pesticide analyses. See Table 2 for a list of the parameters analyzed for and the corresponding laboratory and analytical techniques used.

Field measurements of EC were made using a battery operated Myron Conductivity Meter which was calibrated before each sampling day. Temperatures were measured in the field with a mercury thermometer.

To determine the precision, or reproducibility of the analyses, duplicate samples were taken at 10 percent of the sites sampled, for all parameters measured. The original and corresponding duplicate sample values are shown in Table 3. Table 4 gives the average and range of percent differences between the original and duplicate sample analyses for all of the parameters.

The lab was not able to reproduce the results for alkalinity, boron, orthophosphate, or total phosphate very well. Problems with the alkalinity measurements are probably due to time factors. Unless a sample is analyzed within 24 hours, interaction with other constituents can significantly affect alkalinity analyses. The large percent differences for boron, orthophosphate,

and total phosphate is probably due to the naturally low concentrations of these constituents. A small difference in concentration can appear large on a percentage basis when the actual concentration is itself small.

The accuracy of the analyses were evaluated by submitting 5 "blind" samples of known mineral composition to the laboratory. Table 5 lists the results of the mineral standards analyzed by Anlab. The relative standard deviation of the mineral standards is shown in Table 6. The accuracy of the bicarbonate analyses was low as indicated by a relative standard deviation of 1.25. As mentioned above, this is probably because the lab was not able to analyze the samples within 24 hours of collection. Accuracy of the chloride and sulfate analyses were somewhat low as a result of one analysis which was considerably different than the standard, for both chloride and sulfate.

The analyses for nitrates were generally precise and accurate. As indicated by the mineral standards results in Table 5, the laboratory consistently obtained a somewhat lower than actual value for all the nitrate standard solutions. This indicates that the nitrate values obtained for the study are probably minimum values which may in reality be somewhat higher.

Mineral Quality

Surface Water

Water from the TID irrigation canals, which provides much of the ground water recharge, is of good mineral quality. Two locations sampled each showed a TDS

of less than 100 mg/l and an ED of 110 μ hos/cm or less (see Table 7). Nitrate levels at 3 canal locations were 1.7 mg/l $\text{NO}_3\text{-N}$ or less.

From Table 7 it is apparent that water from dairy ponds is considerably higher in every constituent except nitrate than the irrigation water is. EC and TDS levels are as much as 54 and 31 times, respectively, than in the irrigation water.

Unconfined Aquifer

The mineral quality of ground water in the upper, unconfined aquifer was of main interest, because the poorest quality of water was expected there. Recharge from septic tank systems and irrigation return flows which have been concentrated by evaporation losses tend to increase mineralization in the shallow ground water. Of a total of 69 wells sampled in June, 49 were determined to be perforated in the upper, unconfined aquifer only. These 49 wells were used to characterize the quality of water in the unconfined aquifer. See Table 8 for the mineral analyses of these 49 wells plus 10 additional wells of uncertain or unknown depth which are thought to be perforated in the unconfined aquifer.

In June of 1986 the EC of the water from the 49 wells in the upper aquifer averaged 683 μ hos/cm, ranging from 310 to 1200 μ hos/cm. Chloride concentrations ranged from 9 to 240 mg/l with an average of 49 mg/l. Nitrate levels ranged from <0.01 to 35 mg/l $\text{NO}_3\text{-N}$, averaging 13 mg/l $\text{NO}_3\text{-N}$.

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In June, 34 of these 49 wells showed nitrate levels at or above the drinking water standard of 10 mg/l $\text{NO}_3\text{-N}$. Verification sampling for 33 of these wells was conducted in October 1986 to confirm the initial results. Twenty-eight (28) of these 33 wells also showed nitrate concentrations of 10 mg/l $\text{NO}_3\text{-N}$ or greater in October, ranging from <1 to 38 mg/l $\text{NO}_3\text{-N}$. Seventeen (17) wells showed increases in nitrate concentrations, 15 wells showed decreases, and 2 showed no change. Increases were as little as 1 mg/l $\text{NO}_2\text{-N}$ to as much as 18 mg/l $\text{NO}_3\text{-N}$. Decreases ranged from 1 mg/l to 8 mg/l $\text{NO}_3\text{-N}$.

The 10 wells of unknown or uncertain depth ranged in EC in June from 320 to 1010 $\mu\text{mhos/cm}$, averaging 646 $\mu\text{mhos/cm}$. Chloride analyses were performed on only a few of these wells. Nitrates ranged from 1 to 22 mg/l $\text{NO}_3\text{-N}$, averaging 9.6 mg/l $\text{NO}_3\text{-N}$. In October all of these wells which were 10 mg/l $\text{NO}_3\text{-N}$ or more in June were again above the drinking water standard.

Confined Aquifer

Water from the lower, confined aquifer is expected to be of higher mineral quality because of limited access of surface waters to the deeper zone. However, it is difficult to define the water quality of the confined aquifer since none of the deep wells sampled were properly sealed off from the upper aquifer and many of the wells were perforated in both aquifers. Thus, most water sampled from the deeper wells was probably composite water from both aquifers.

Ten of the 69 wells sampled were determined to be perforated in the lower, confined aquifer. In June, these 10 wells ranged in EC from 190 to 1000 $\mu\text{mhos/cm}$ with an average of 580 $\mu\text{mhos/cm}$ (see Table 9 for the mineral analyses of these 10 wells). Chloride concentrations ranged from 10 to 70 mg/l, averaging 32 mg/l. Nitrate concentrations ranged from <0.01 to 25 mg/l $\text{NO}_3\text{-N}$ with an average of 6.7 mg/l $\text{NO}_3\text{-N}$.

Two of these deep wells showed nitrate concentrations above the drinking water standard in both June and October. One well decreased from 25 mg/l to 17 mg/l between the June and October samplings. The other well showed an increase from 18 to 23 mg/l $\text{NO}_3\text{-N}$.

Background Water Quality

Five wells in the unconfined aquifer were determined to represent background water quality. These wells were located in either grain, hay, or alfalfa fields or in an orchard and apparently were not influenced by any possible nitrate sources. The nitrate concentrations for these 5 background wells averaged 0.23 mg/l $\text{NO}_3\text{-N}$, ranging from <0.01 to 0.80 mg/l $\text{NO}_3\text{-N}$. Chloride concentrations ranged from 10 to 110 mg/l, averaging 38 mg/l. EC values averaged 513 $\mu\text{mhos/cm}$ and ranged from 350 to 890 $\mu\text{mhos/cm}$.

Water from 3 wells perforated in the confined aquifer were determined to most likely represent water quality in that aquifer. These 3 wells are perforated only below the confining clay layer and do not appear to be greatly affected by

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any outside nitrate sources. The average nitrate concentration for these 3 wells is 1.5 mg/l $\text{NO}_3\text{-N}$ and ranges from 0.6 to 3.2 mg/l $\text{NO}_3\text{-N}$. Chloride concentrations range from 10 to 31 mg/l, averaging 17 mg/l. The EC averages 347 $\mu\text{mhos/cm}$ and ranges from 190 to 580 $\mu\text{mhos/cm}$.

Areas of Nitrate Occurrence

Figure 6 shows the locations and nitrate concentrations from the June sampling for wells perforated in both the unconfined and confined aquifers. Forty-one (41) of the 69 wells sampled in June showed nitrate concentrations greater than 10 mg/l $\text{NO}_3\text{-N}$. Thirty-five (35) of these wells also showed nitrate concentrations above the drinking water standard in October.

The June nitrate concentrations are compared with the current land uses in Table 10. From the table it is apparent that almost all of the land uses listed are potential sources of excessive nitrates in the ground water. It is difficult to determine the exact source of most high nitrate areas since most of the wells have land uses both at the site and up ground water gradient which are potential nitrate sources. However, dairies and grain and corn crops are clearly implicated as sources of high nitrate concentrations. These 2 sources are directly interrelated in the Hilmar area since about 89 percent of the total acreage for grain and corn crops in the study area receives dairy wastes as a fertilizer. Most of the dairy wells with high nitrate concentrations are down ground water gradient from a grain and/or corn field which is most likely fertilized with wastes from the dairy at which the well is located. Similarly,

the majority of the grain and/or corn fields which show nitrate concentrations above the drinking water standard are either very close to a dairy or down ground water gradient from a dairy and are likely to receive dairy wastes as a fertilizer.

Most of the other high nitrate areas are in close proximity to, or down ground water gradient, from a dairy or a grain and/or corn field which may be fertilized with dairy wastes. Two urban wells down ground water gradient from the one golf course in the area and 2 wells within 100 feet north of the golf course show nitrate concentrations above 10 mg/l $\text{NO}_3\text{-N}$.

In general, the average June nitrate concentrations in the unconfined aquifer decreased with depth (see Table 11). Of 49 wells perforated in the unconfined aquifer, 34 in June and 28 in October had 10 mg/l $\text{NO}_3\text{-N}$ or more. Two of the 10 wells perforated in the confined aquifer had nitrate concentrations above the drinking water standard both in June and October. Neither of these 2 deep wells has a surface seal and one of the 2 is perforated throughout the entire length of the casing, while the other is gravel packed throughout the entire casing length (no information is available on the perforation interval). Thus, water from both of these deep wells is probably composite water from both aquifers and the high nitrate levels may actually result from water in the unconfined aquifer. Four of the other deep wells which are known to be perforated only below the confining E-clay all show nitrate concentrations below 10 mg/l $\text{NO}_3\text{-N}$.

Salinity

The UC Guidelines for the quality of irrigation water suggests that an EC between 750 and 3,000 $\mu\text{mhos/cm}$ may cause "increasing problems" for some crops. "Severe problems" are encountered at EC levels above 3,000 $\mu\text{mhos/cm}$. Thus, those wells which showed an EC of 750 $\mu\text{mhos/cm}$ or more were looked at in this study.

Of 69 wells sampled in June, 23 had an EC of 750 $\mu\text{mhos/cm}$ or more. Seventeen (17) of the 35 wells sampled in October had an EC of 750 $\mu\text{mhos/cm}$ or more. The maximum levels in both June and October were 1200 $\mu\text{mhos/cm}$. The maximum level in the unconfined aquifer was 1200 $\mu\text{mhos/cm}$. In the confined aquifer it was 1000 $\mu\text{mhos/cm}$.

Some of the crops grown in this area may show a slight yield decrement at the higher EC levels present. Corn, almonds, and sweet potatoes are some of these crops. The reduced yield for any one of these crops would probably not be more than 5 percent of the maximum yield.

Although the higher levels of EC (750 $\mu\text{mhos/cm}$ or more) are commonly associated with dairies or corn, as are nitrate levels above 10 mg/l $\text{NO}_3\text{-N}$, there does not appear to be a definite linear relationship between EC and nitrate levels. In fact, while the nitrate concentrations decrease with depth in the unconfined aquifer, the average salinity increases with depth (see Table 11).

The Environmental Protection Agency (EPA) has established a total dissolved solids (TDS) concentration of 1000 mg/l as a drinking water standard. The

maximum TDS in any of the ground water analyzed in this study was 760 mg/l. Thus, as far as the TDS is concerned, the ground water should not cause any health related problems when used as drinking water.

Pesticides

Fifteen (15) wells were sampled for pesticides. These wells were either in or down ground water gradient from an almond orchard, corn, oats, alfalfa, sudan, mixed pasture, or a golf course. All wells were sampled for organochlorine pesticides and PCBs, organophosphorus pesticides, carbamate and urea pesticide, triazine pesticides, and thiocarbamate compounds. Nine (9) of these wells were also sampled for DBCP, a persistent nematicide commonly used on grapes and citrus before it was removed from the market in 1977. No pesticides were detected in any of the wells (see Table 12).

Nutrients

Nutrient analyses were performed on water from 14 wells, 2 dairy ponds, and a TID irrigation canal. All 14 wells sampled draw water from the unconfined aquifer. The analyses included measurements of total kjeldahl nitrogen (TKN), ammonia ($\text{NH}_3\text{-N}$), total phosphate (P), orthophosphate ($\text{PO}_4\text{-P}$), potassium (K), and nitrate ($\text{NO}_3\text{-N}$). See Table 13 for nutrient analyses on the ground water samples and Table 14 for nutrient analyses on dairy ponds and irrigation water.

In June the TKN ranged from <0.06 mg/l to 0.84 mg/l TKN-N, averaging 0.41 mg/l TKN-N for 7 wells, ranging from 0-.1 mg/l to 0.8 mg/l TKN-N. No $\text{NH}_3\text{-N}$ was

detected in any of the June samples. Due to laboratory problems, no $\text{NH}_3\text{-N}$ analyses were performed in October.

Levels of TKN which exceeded the ammonia levels in 9 wells indicate the presence of organic nitrogen in these wells, since TKN is a measure of ammonia and organic nitrogen forms such as urea, amino acids, and proteins. Seven (7) of these 9 wells also showed nitrate concentrations exceeding 10 mg/l $\text{NO}_3\text{-N}$. Six (6) wells were located on dairies and 3 were located in crop fields which are either immediately down ground water gradient from a dairy or which are fertilized with dairy wastes.

Two (2) wells (6S 10E 26G and 6S 10E 26L), located in agricultural fields which do not receive dairy wastes as a fertilizer, showed no detectable levels of TKN. Both wells also showed low $\text{NO}_3\text{-N}$ concentrations of 0.05 mg/l and 2.1 mg/l, respectively.

Thus, in general, organic nitrogen is common in wells located on dairies or croplands receiving dairy wastes, both of which are also likely to show nitrate levels above 10 mg/l $\text{NO}_3\text{-N}$. Ground waters with no detectable TKN also showed low nitrate levels and are associated with croplands which are not fertilized with dairy wastes.

TKN-N and $\text{NH}_3\text{-N}$ concentrations in the TID canal water were 0.39 mg/l and <0.02 mg/l, respectively. The source water for the TID irrigation canals, the Tuolumne River, is probably much lower in TKN. The higher levels observed in the canal

water may be due to the discharge of ground water from the TID Drainage wells into the canal.

TKN and NH_3 levels in water from dairy ponds are typically much higher than levels observed in ground and surface waters. The dairy pond sampled in this study showed 310 mg/l TKN-N and 240 mg/l NH_3 -N. Due to conversion of most or all of the organic nitrogen to ammonium ions little, if any, organic nitrogen is typically found in ground water. In 101 ground water samples from a high nitrate area in and around Chico, the TKN-N averaged 0.08 mg/l and ranged from 0.0 to 1.6 mg/l (DWR, January 1984). The Chico area is a predominately urban area with some orchards and a few other crops present. The high nitrate levels there were determined to the result of the widespread use of septic tanks.

Potassium levels in the irrigation and ground waters were not unusually high. A 1.1 mg/l K was observed in the canal water and 1.5 mg/l to 5.6 mg/l K was observed in the ground water. Potassium levels in natural ground waters are commonly at similar low concentrations. Levels of K in the 2 dairy ponds, 130 mg/l and 420 mg/l, were much higher. It is apparent that although waste water from dairy ponds contribute considerable amounts of K to the soil, very little is leaching into the ground water. This is probably due to the adsorption of potassium ions into clay particles in the subsoil.

Of 10 wells sampled for phosphates in June, 8 showed at least some organic phosphorus to be present (i.e., total phosphates was greater than orthophosphates). These 8 wells ranged from 0.11 mg/l to 0.26 mg/l total phosphates, averaging 0.18 mg/l. The levels of organic phosphorus present (total

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phosphate minus orthophosphate) ranged from 0.03 mg/l to 0.23 mg/l, with an average of 0.12 mg/l. Six (6) of the 8 wells are located on dairies. The remaining 2 wells are located in agricultural fields, both of which are fertilized with dairy wastes. The highest level of organic phosphorus, 0.23 mg/l, was observed in a well located at a dairy.

Two (2) wells showed no organic phosphorus to be present in June. One (1) of these 2 wells (6S 10E 17J) showed total phosphates as high as 0.90 mg/l and is located in an alfalfa field. Alfalfa is commonly fertilized with inorganic phosphorus. The other well (6S 10E 26G) which showed no organic phosphorus to be present had a much lower total phosphate level. It is located in a grain field which is not fertilized with dairy wastes.

Ten (10) wells sampled in October all showed some presence of organic phosphorus. The total phosphate for these 10 wells ranged from 0.06 mg/l to 0.9] mg/l, with an average of 0.20 mg/l. Organic phosphorus ranged from 0.02 mg/l to 0.12 mg/l, with an average of 0.06 mg/l. Seven (7) of these wells are located on dairies, 2 are in crop fields which receive dairy wastes as a fertilizer, and 1 is in an alfalfa field.

Since most natural ground waters have less than 0.1 mg/l phosphorus (Bower, 1978), these wells, which averaged 0.18 mg/l and 0.20 mg/l total phosphates in June and October, respectively, show that the ground water in the study area is higher in phosphorus than normal. The highest level of organic phosphorus occurred at a dairy well, and the highest level of total phosphate, all of which

was in the inorganic form as orthophosphate, occurred in a well located in an alfalfa field.

Phosphorus levels in the TID canal water were 0.12 mg/l total phosphates and 0.05 mg/l orthophosphates. The phosphorus levels in the 2 dairy ponds were very high, with 180 mg/l and 110 mg/l total phosphate and 22 mg/l and 84 mg/l orthophosphate. Thus, water from dairy ponds which is used to irrigate crops is obviously a source of both inorganic and organic phosphorus. The lower levels observed in the ground water result from the adsorption of phosphorus to clay particles or to chemical precipitation. Higher than normal phosphorus concentrations may occur in ground water when the sorptive capacity of the soil is exceeded.

In summary, total phosphate and TKN were both typically higher in these wells than is normally found in ground water. Potassium levels were normal for natural ground waters. Organic forms of nitrogen and phosphorus occurred in all dairy wells and wells located in crop fields which are fertilized with dairy wastes. All but 2 of those wells also showed significant levels of $\text{NO}_3\text{-N}$, usually above 10 mg/l. A high level of inorganic phosphorus was present in 1 well located in an alfalfa field.

Two wells located in crop field which did not receive dairy wastes as a fertilizer (6S 10E 26G and 6S 10E 26L) showed no organic nitrogen to be present, and at least 1 of the 2 had no organic phosphorus present as well (the other well was not analyzed for phosphates). The $\text{NO}_3\text{-N}$ levels in these 2 wells were also low.

From these nutrient analyses it appears that dairies are a potential source of higher than normal levels of nitrates and organic forms of nitrogen and phosphorus in ground water. While only 2 nutrient analyses of commercially fertilized crop areas were performed, it appears that commercially fertilized croplands may be less likely to significantly affect nitrate and organic nitrogen and phosphorus levels in ground water.

SOURCES OF NITRATES AND SALTS

Because of the large number of dairies and acres of crops grown, animal wastes and fertilizers are the major sources of nitrates in the Hilmar area. Septic systems can also make significant contributions, but because of the low population density in this area, they are not as significant a source of either nitrates or salts. Nitrogen fixation and decomposing organic matter are also of less importance. Because of the high quality of both rain and irrigation water, there is little contribution to the total salt or nitrate load from either of these sources. Nor are the continental deposits of the 2 water-bearing units a significant source of nitrates or salts.

Processes in the unsaturated zone which prevent nitrogen from reaching the ground water include plant uptake, ammonia volatilization, adsorption or cation exchange of ammonium ions, and denitrification. These processes are examined more closely in the discussion below on the nitrogen cycle.

Nitrogen Cycle

Atmospheric nitrogen is the ultimate source of nitrogen used by plants. The processes by which it is incorporated into the soil, utilized by plants, and eventually returned to the atmosphere are all part of the nitrogen cycle (see Figure 7).

The nitrogen cycling is a natural ecosystem, is highly efficient, and leaching of nitrate into the ground water is minimal. In an agro-ecosystem, however, the efficiency of the nitrogen cycling is much lower due to increased nitrogen inputs in the form of fertilizers and nitrogen fixation by leguminous plants. When the nitrogen supply is greater than what can be used by the plants, then nitrogen can be lost from the soil by volatilization, denitrification, immobilization or tie-up by soil bacteria, or leaching into the ground water.

All sources of nitrogen, whether organic or inorganic, may undergo nitrification to form nitrate-nitrogen. Organic nitrogen compounds such as proteins, amino acids, amides, nucleic acid, urea, etc., must first be mineralized by microbial decomposition to produce ammonia, or ammonium, before nitrification can occur.

Ammonium, either originating from organic or inorganic sources, may be taken up by plants or undergo adsorption, cation exchange, incorporation into the microbial biomass, release to the atmosphere in the gaseous form, or nitrification.

Most nitrogen utilized by plants is in the nitrate form. However, some ammonium is used by plants.

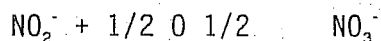
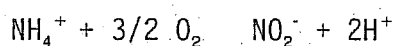
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Adsorption and cation exchange of ammonium ions occurs in anaerobic conditions. The positively charged ammonium ions are readily adsorbed onto negatively charged soil particles, or they exchange sites with other cations on the soil particles.

Soil microorganisms require carbon and nitrogen in their development. Inorganic nitrogen, in the form of NH_4^+ , can be converted to organic nitrogen in the formation of microbial protein by these microorganisms. This makes the nitrogen at least temporarily inaccessible to plants or to leaching.

When applied to soil, ammonium may volatilize to the atmosphere as ammonia gas. This is a chemical reaction which occurs readily in calcareous soils at high pH.

If aerobic conditions exist, as is common in unsaturated, sandy soils, autotrophic bacteria may convert the ammonium ion to nitrate (NO_3^-) by the following reactions:



The negatively charged nitrate ions do not adsorb to negatively charged soil particles. They are thus more soluble and mobile than ammonium ions in both saturated and unsaturated soils and leach to the ground water readily. Nitrate which is not leached away or utilized by plants may form N_2O or N_2 gases upon denitrification. Denitrification of nitrate ions is a biological process which

occurs under anaerobic conditions in the presence of heterotrophic bacteria. Dentrification may occur in saturated soils or in ground water.

Atmospheric nitrogen may enter the soil system through fixation by symbiotic or free-living bacteria or by fixation of one of the oxides of nitrogen by lightning. Symbiotic nitrogen fixation by bacteria such as Rhizobia and legumes such as alfalfa can convert elemental atmospheric nitrogen to a form which is useable by the host plant. Nitrogen fixation by this process can be as high as 400 lbs/acre/yr (Murphy, 1978), some of which is utilized by the host plant itself and some of which is left as plant residue after harvest.

Non-symbiotic nitrogen fixation by bacteria such as blue-green algae and certain free-living bacteria can also convert atmospheric nitrogen to forms useable by plants. This process probably only accounts for the fixation of about 6 lbs of N/acre/yr (Murphy, 1978).

Lightning can convert N_2 in the atmosphere to oxides of nitrogen such as NO , NO_2 , or NO_3 . Ammonia gas is also common in the atmosphere in industrial areas. These sources of nitrogen are brought to the soil by rainfall.

Animal Wastes

Dairies are the largest source of animal wastes in the Hilmar area. There are currently about 60 operating dairies, 3 poultry farms, and several abandoned dairies. Forty-seven (47) of the 60 dairies and all 3 poultry operations were

surveyed in order to determine management practices common to the Hilmar area and to obtain an estimate of nitrogen and salt loading due to these operations.

Most of the dairy and poultry wastes are used to fertilize some of the crops grown in the Hilmar area. The effect that these animal wastes can have on the quality of the ground water is influenced by soil type, depth to ground water, irrigation practices, crop type, and application rate. Management practices such as the methods of handling, storing, and applying animal wastes to crops are also important factors.

Most of the Hilmar area is characterized by loamy sand, sand, or sandy loam soils. Permeability is typically rapid in the surface soil, but slow to very slow in the subsoil. Slopes are generally no more than 3 percent, resulting in slow surface runoff (USDA, 1950).

The depth to the water table varies naturally from about 5 feet to 26 feet below the ground surface. Operation of the TID drainage wells maintains the water table at least 6 feet below ground surface in many areas.

Most irrigation water is provided by the TID canals which transport water from the Tuolumne River to the San Joaquin River. A few growers use water from their own wells. The irrigation season is typically from early March to late October.

The most common crops fertilized with dairy wastes are corn and oats with most dairies following a summer corn crop with oats in the fall. A total of about 7,115 acres are used by the 47 dairies surveyed for application of dairy wastes

to crops. Approximately 5,200 of these acres are used to grow corn and oats. About 1,300 acres are used for growing alfalfa.

Sudan, pasture, and almonds each account for 120 acres or less of dairy waste disposal. Of these 5 crop types, corn and almonds have the highest nitrogen requirements.

Dairy wastes are usually generated in corrals and milking areas. Mostly solid wastes accumulate in the corral area, while large volumes of liquid wastes are produced in the milking area. Before application to cropland, the solid wastes can be stockpiled or disposed of in holding ponds. Frequently, some of the solid wastes are hauled away. Liquid wastes may be discharged directly to a field or to a holding pond before being distributed for irrigation. Use of holding ponds for storage of liquid and solid wastes produced in the milking areas is common in the Hilmar area. Forty-five (45) of the 47 dairies surveyed use ponds for dairy waste storage. In addition, all but 3 dilute their wash water before applying to crops.

Both stockpiling and holding animal wastes in ponds results in nitrogen losses through volatilization. The amount of nitrogen lost is dependent on the amount of time between storage and use. For storage of 30 days or less in a holding pond 30% of the nitrogen is lost, while a storage period of 60 days or more results in an approximately 50% loss of nitrogen (Meyer, Rauschkilb, Olson, 1975). In the Hilmar area holding ponds are commonly pumped at each irrigation during the dry season, but may be pumped as frequently as daily or as infrequently as once a month. During the winter months holding times are

generally longer, with pumping typically occurring as infrequently as once every 3 months. Thus, a removal of 50% of the initial nitrogen is more common in the winter months when holding times are longer, while a 30% nitrogen removal during the irrigation season is more typical.

Loss of total nitrogen from manure exposed to drying can be as great as 50% within 7 to 8 days, while stockpiling fresh manure under anaerobic conditions can result in a loss of as little as 8% during a period of 50 days (Azevedo, 1974). Since most corral manures in Hilmar are not stockpiled more frequently than once every week, an average total nitrogen loss of 50% from corral manure is probably typical.

Fertilizers

Commercial fertilizers are used on almost half of the cropland acres in the study area. Like animal wastes, the effect that these fertilizers can have on ground water quality is also influenced by soil type, depth to ground water, irrigation practices, crop type, and application rate. The form of fertilizer may also have an effect on the amount of nitrates leaching to the ground water.

Table 13 lists the crops grown in the Hilmar area with the corresponding recommended fertilizer application rates and types of fertilizer commonly used for each crop type. In addition, an estimate is made of the amount of salts that are contributed by the fertilizers used on each crop. It is assumed that each fertilizer is 100% salts. It should be noted that the applied salts do not

necessarily remain in a one-to-one relation in the soil. Some salts may adsorb to soil or organic particles or form precipitates in the soil.

Recommended fertilizer application rates vary from about 30 lbs N/acre/yr for alfalfa and dry beans to 200 lbs N/acre/yr for corn and lawns. Although all crops are commonly fertilized at rates in excess of that recommended, lawns typically receive the greatest excess fertilizer. An application rate of 500 lbs/N/acre/yr is not unusual for lawns, especially on golf courses. In addition to high fertilizer application rates, lawns typically require high water application rates. This increases the leaching of nitrates to the ground water.

Table 14 lists the 5 most common sources of fertilizer nitrogen for Merced County in 1986. Eighty percent (80%) of the fertilizer nitrogen was derived from these 5 sources. Half of this nitrogen (or about 41% of the total nitrogen applied in Merced County) was from urea ammonium nitrate. Aqua ammonia is the second most significant source of nitrogen (14.5% of the total). __, ammonium sulfate, and urea each contribute 7-8% of the total applied nitrogen. Several other forms of nitrogen fertilizers each contribute lesser amounts of nitrogen. A small part of the study area is in Stanislaus County. Urea ammonium nitrate makes up about 37% of the total applied fertilizer nitrogen there. Anhydrous ammonia and ammonium sulfate each make up 19% and 10%, respectively, of the total fertilizer nitrogen in Stanislaus County.

Ammoniacal forms of nitrogen tend to transform rapidly to nitrate in soils where plants are actively growing. Applying these forms of nitrogen in concentrated

bands may help to reduce nitrification to nitrate. This allows more ammonia to be adsorbed to clay particles, resulting in a lower leaching potential.

Domestic Wastes

Only the City of Hilmar, a small portion of the entire study area, is on a sewer system. The surrounding areas treat domestic wastes in septic tanks which discharge waste effluents through subsurface leach fields.

Water used for domestic purposes can show increases in total nitrogen content of 20 to 40 mg/l. Conversion to nitrate could result in the undiluted leachate containing 2 to 4 times the acceptable drinking water level (DWR, 1984). However, denitrification, ammonia volatilization, and plant uptake remove some of the nitrates in the unsaturated zone. The unsaturated zone in the Hilmar area is commonly less than 20 feet, limiting the nitrogen removal process.

Because of the greater density of animals on dairies and poultry farms, the large number of animal facilities in the Hilmar area, and the fact that 1 average milk cow produces an amount of nitrogen equivalent to 17 humans (CRWQCB, 1975), the contributions of nitrates to ground water through individual domestic septic systems is much less than that contributed by animal wastes.

Nitrogen Fixation

Free-living bacteria in soils can fix atmospheric nitrogen into nitrogenous compounds. These bacteria generally fix no more than 25 pounds of nitrogen

annually per acre (Brady, 1966). In fertilized soils which have readily available ammoniacal and nitrate nitrogen, the fixation of atmospheric nitrogen is greatly reduced. Thus, in the intensively farmed Hilmar area nitrogen fixation by free-living bacteria is probably insignificant.

Fixation of atmospheric nitrogen in association with symbiotic bacteria and leguminous plants such as alfalfa, clover, and beans can result in fixation of several hundred pounds of nitrogen per acre. However, some of this fixed nitrogen is used by the host plant, passed into the soil and used by nearby plants, or used by subsequent crops.

Alfalfa and beans are 2 leguminous plants grown in the Hilmar area. Together they, make up about 11% of the total cropland. Thus, they do not contribute a great deal of nitrogen to the study area in comparison to that contributed by animal wastes and commercial fertilizers.

Decomposing Organic Matter

The accumulation and decomposition of organic materials can supply nutrients to succeeding crops. Most of these nutrients are recycled in the soil-vegetation system during decomposition, but some are leached down to the water table. Only leguminous plants supply enough nitrogen upon decomposition to be important in the leaching of nitrates to the ground water. The effect of leguminous plants is discussed in the previous section on nitrogen fixation.

Irrigation Water

Since the majority of the irrigation water in the study area comes from the Tuolumne River which is of high quality, the contribution of salts and nitrogen from this source is minor compared to the other major sources. A small percentage, about 15%, of irrigation water is obtained from wells penetrating both the unconfined and confined aquifers. Since using ground water for irrigation merely recycles nitrogen and salts, with some losses of both certainly occurring, it is assumed that no additional salts or nitrogen are contributed to the ground water by such use.

Rainfall

The contribution of salts and nitrogen due to rainfall is negligible since the area has a low annual precipitation rate and rain water quality is good. The average annual precipitation is 11.692 inches (DWR, 1982) and nitrate concentrations of rain water are typically less than 0.50 mg/l NO_3 in this area (Air Resources Board, 1986).

Geology

Geologic sources of nitrogen are generally associated with sediments deposited in a marine environment which is rich in organic material. The sediments making up the 2 aquifers in this area are derived from continental deposits originating from the Sierra Nevada and do not contain much organic material. Thus, the sediment making up the 2 water bearing units are very unlikely to be sources of nitrates in the ground water.

NITROGEN AND SALT LOADING

An estimate of the nitrogen and salt loading due to each of the various potential sources has been made to determine which sources are likely to have the most significant effect on ground water quality. The loading rates determined are estimates only and are based on current information available from literature and people who are qualified in specialized areas.

Animal Wastes

Forty-seven (47) of the 60 currently operating dairies and the 3 poultry farms in the study area were surveyed to estimate the average nitrogen and salt loading due to these operations. Both the dairy and poultry surveys obtained information on the number of animals at each facility, the percentage of manure which is handled wet or dry, how many acres are used for waste disposal, what crops are fertilized with the wastes, how much manure is hauled away annually, whether or not a holding pond is used, and how frequently holding ponds are pumped (see Appendix A for the dairy and poultry operation survey forms). From this information an estimate was made of the annual average nitrogen and salt loading per acre and the total nitrogen and salt loading due to the 47 dairies and 3 poultry operations (see Appendix B for the methods of calculating salt and nitrogen loading). The range of nitrogen and salt loading was also determined for both dairy and poultry operations.

The 47 dairies surveyed contribute a total of about 578 tons of nitrogen per year over a total of 7,115 acres. This results in an average nitrogen loading of about 162 lbs N/acre/yr. The estimated total nitrogen is a conservative estimate since 15 dairies were not surveyed. The individual loading rates range from 27 to 1,063 lbs N/acre/yr. Smaller dairies typically contribute the largest nitrogen loading rates.

The total annual salt loading for the 47 dairies was estimated to be 7,157 tons with an average loading rate of approximately 2,000 lbs salt/acre/yr. The loading rates range from about 405 to 12,355 lbs salt/acre/yr.

An estimate of the total nitrogen loading due to all 70 dairies can be made using an average of 12.3 tons N/dairy/yr to the 15 dairies not surveyed gives an additional 1.84 tons N per year, for a total of 762 tons N/yr being contributed by dairies. Similarly, using an average of 152 tons salt/dairy/yr (7,157 tons salt/yr divided by 47 dairies) given an additional 2,284 tons of salts contributed by the 15 dairies not surveyed, for a total annual salt loading of 9,441 tons due to dairies.

The 3 poultry operations contribute an estimated total of 257,040 pounds (129 tons) of nitrogen per year to 855 acres, for an average of 301 lbs N/acre/yr. The total annual salt loading was estimated to be about 716 tons salt/yr. Over 855 acres this is an average of 1,674 lbs salt/acre/yr. The range of salt loading is 982 to 2,048 lbs/acre/yr.

The total estimated annual nitrogen loading from all dairies and poultry operations is 891 tons. The total salt load is 10,157 tons/yr. This is applied to approximately 10,241 acres. The average annual nitrogen and salt loadings from both dairy and poultry wastes are thus approximately 174 lbs N/acre/yr and 1.984 lbs salt/acre/yr. The types and amounts of the different crops which are fertilized using dairy and poultry wastes are listed in Tables 15 and 16.

Assuming that approximately 50% of the applied nitrogen is utilized in the root zone, the amount of nitrogen leaching to the ground water may be as much as 446 tons N/yr.

Fertilizers

Crop acreages for the study area were determined using the DWR 1980 land use maps for Merced and Stanislaus Counties. Of a total of 22,520 acres in the entire study area, approximately 86%, or 19,342 acres, are used as cropland. Corn (frequently double-cropped with oats), almonds, and alfalfa make up almost 80% of all crops grown. Corn is grown on about 8,604 acres (44% of the total crop acreage), almonds on about 4,823 acres (25% of the total crop acreage), and alfalfa on about 1,945 acres (10% of the total crop acreage). Table 17 lists other crop acreages.

Table 17 lists the approximate acres of each crop type which are fertilized with animal wastes or commercial fertilizers. Corn, the predominant crop grown in the area, and alfalfa are both fertilized mainly with animal wastes. Commercial

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fertilizers are used mostly for supplying nutrients to almonds. Over half of the commercially applied nitrogen is used to grow almonds, while approximately 18% is used to grow corn. All other crop types each use 6% or less of the total commercially applied nitrogen.

The estimated total amount of commercially applied nitrogen and salts is shown in Table 17. Approximately 577 tons of nitrogen and 2,818 tons of salts are applied annually to all of the commercially fertilized crops. Assuming there is 50% utilization of nitrogen in the root zone, the amount of nitrogen from commercial fertilizers which may leach to the ground water could be as high as 288 tons per year.

Domestic Wastes

Unsewered Residential Areas

Approximately 22,000 acres of the study area is unsewered. With an estimated population density of 35 residents per 1,000 acres, there are approximately 770 housing units served by septic tanks. The average septic tank serves 3.5 persons and generates 12 to 18 lbs nitrogen per person per year (Andreoli, 1979). Thus, the estimated annual nitrogen load from septic tanks is approximately 16 to 25 tons N/yr.

The average TDS for septic tank effluent is 300 mg/l (Metcalf, 1972). At an estimated septic tank discharge of 75 gallons/capita/day this is equal to approximately 92 tons of salts/yr.

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Sewered Residential Areas

The City's sewage treatment plant is located in the southeastern portion of the study area. It serves approximately 2,500 people and has an average flow rate of about 0.19 million gallons per day (mgpd), ranging from 0.18 to 0.20 mgpd. The treated effluent is applied to 20 acres of grass and/or alfalfa.

Purified sewage effluent contains approximately 40 mg/l nitrogen ($\text{NO}_3\text{-N}$) and 300 mg/l TDS (Metcalf, 1972). For an average flow rate of 0.19 mgpd this is equal to approximately 12 tons N/yr and 87 tons salts/yr. A 50% utilization of nitrogen in the root zone is not assumed since the rate of applied nitrogen (1200 lbs N/acre/yr) is much greater than the requirements of any crop.

Nitrogen Fixation

Nitrogen fixation by Rhizobium microorganisms in association with leguminous plants can account for about 101 pounds of nitrogen per acre per year for alfalfa and about 13 pounds of nitrogen per acre per year for beans (Pettygrove, 1987). These are the amounts of fixed nitrogen which remain in the soil after harvest. Thus, 1945 acres of alfalfa and 154 acres of beans would fix approximately 90 and 1 ton(s) of nitrogen per year, respectively. Assuming 50% utilization in the root zone by succeeding crops, approximately 50 tons of symbiotically fixed nitrogen may leach into the ground water.

As mentioned previously, nitrogen fixation by free-living bacteria is probably insignificant in this intensively farmed area.

Irrigation Water

The study area receives approximately 3.6 feet of irrigation water annually from the Tuolumne River, via the TID irrigation canals. The irrigation water averages about 1.1 mg/l $\text{NO}_3\text{-N}$ and 88 mg/l TDS (see Table 7). Approximately 85% of the 19,342 acres of cropland, or 16,441 acres, receive irrigation water from the TID canals. The irrigation water thus contributes about 88 tons of nitrogen and 7,073 tons of salts annually to these 16,441 acres. Assuming 50% utilization of nitrogen in the root zone the amount of nitrogen which may leach to the ground water is approximately 44 tons.

Evaluation of Mass Balance

Based on the discussion above, the contributions of nitrogen and salts from the various sources are as follows:

The percentages above indicate that animal wastes and fertilizers account for approximately 85% of the total nitrogen loading. Approximately 446 tons of nitrogen from animal wastes are applied over 10,241 acres annually, for an average loading rate of 87 lbs N/acre/yr. The average nitrogen loading rate for commercial fertilizers is 63 lbs N/acre/yr (288 tons N/yr applied over 9,101 acres). The actual loading rate for fertilizers may be higher due to individual application rates which commonly exceed the recommended rates. Although the loading rates for these 2 sources are only rough estimates, it is apparent that the application of animal wastes and commercial fertilizers are the predominant sources of nitrogen in this area.

The application of animal wastes and irrigation water to cropland accounts for about 85% of the total salt loading. 10,157 tons salt/yr applied over 10,241 acres is an approximate average salt loading of 1,984 lbs salt/acre/yr due to animal wastes. The approximate average annual salt loading due to irrigation water is 860 lbs salt/acre/yr (7,073 tons applied over 16,441 acres, assuming 85% of the total crop acreage receives TID irrigation water). Thus, based on pounds of salt per acre, animal wastes contribute the most significant amounts of salts to the area which may be leached to the ground water.

WELL CONSTRUCTION

Some well construction methods can increase the likelihood of nitrates entering either the unconfined or the confined aquifer. The practice of completing a well without a sanitary surface seal allows surface water to move readily down the annular space of the well and into the upper aquifer, carrying possible

contaminants with. it. Contamination of the lower aquifer can occur when the perforation interval of the well covers both aquifers, or even when the perforation interval covers the lower aquifer only, if there is no seal between the 2 aquifers. This is especially likely when the head in the upper aquifer is higher than the head in the lower, confined aquifer, as is the case in the Hilmar area. The location of the well is also important. The nearer the well is to the source the more likely it is that contaminated surface waters can move down the well's annular space and into the ground water.

Of 35 wells in the study area with available information on whether or not a sanitary surface seal was provided, 22 have a seal and 13 do not (see Table 18, Well Data). At least 2 of these wells without a seal are dairy wells. Bentonite and cement are both common sealing materials. At least 2 of the 10 wells drilled into the lower aquifer have perforations over the entire length of the casing. Both of these wells show nitrate concentrations which are above background levels. One showed nitrate concentrations above the drinking water standard in June and October. The other well had a nitrate concentration of 9.1 mg/l in June. None of the 4 wells that are perforated in the confined aquifer only have a seal separating the upper and lower aquifers. One of these 4 wells showed a nitrate concentration of 9 mg/l $\text{NO}_3\text{-N}$ in June, a level which is well above the background level.

The Merced County Health Department has a minimum required spacing of 100 feet between a well and a septic tank or corral. In areas of high ground water this minimum distance is 150 feet. There is no required minimum distance between wells and other possible sources of nitrogen, such as croplands fertilized with

either animal wastes or commercial fertilizers. In fact, it is very common for wells with no sanitary surface seal to be located in the middle of crop fields.

It is apparent that well construction methods used in the study area may increase the chance of nitrates entering the ground water. Many wells have been constructed without a sanitary surface seal and/or very near potential nitrogen sources. They may thus allow contaminated surface water to enter the ground water. In addition, deep wells are commonly perforated across both aquifers, or if only perforated in the lower aquifer, they are not likely to have a seal between aquifers. Both of these construction practices for deep wells increase the chances that contaminated water of the upper aquifer may enter the lower aquifer.

SUMMARY

Of 69 wells sampled in June, 41 showed nitrate concentrations at or above the drinking water standard of 10 mg/l $\text{NO}_3\text{-N}$. Nitrate concentrations in June ranged from <0.1 mg/l to 35 mg/l $\text{NO}_3\text{-N}$. Thirty-five (35) of 40 wells which showed nitrate concentrations exceeding 10 mg/l $\text{NO}_3\text{-N}$ in June also showed nitrate levels above the drinking water standard in October. October nitrate levels were as high as 38 mg/l $\text{NO}_3\text{-N}$. Almost as many wells showed a decrease in nitrates from June to October as those that showed an increase.

Although in general the nitrate concentrations tend to decrease with depth, excessive levels occur in wells drilled into the confined aquifer as well as the unconfined aquifer. Water sampled from deep wells may actually be composite

water from both aquifers. The highest levels of 30 mg/l NO_3 or greater occurred in wells as deep as 115 feet. All but one of these wells with 30 mg/l $\text{NO}_3\text{-N}$ or more is either located at a dairy or immediately down ground water gradient from a dairy or a crop field which receives dairy wastes as a fertilizer. The one exception is a well which is immediately down ground water gradient from the golf course.

Due to the non-point nature of the major nitrogen sources, it is difficult to determine a definite source for many of the nitrate contaminated wells. However, excessive nitrate levels are common in wells located at dairies and in corn and grain fields which are likely to receive dairy wastes as a fertilizer. All wells located near the golf course and many wells in orchards, alfalfa fields and pasture also have nitrate levels of 10 mg/l $\text{NO}_3\text{-N}$ or greater.

Of a total of 19,342 crop acres in the area, over half (10,241 acres) are fertilized with dairy wastes. The rest receive commercial fertilizers. Corn and corn double-cropped with oats receive most of the dairy wastes, while almonds receive the majority of commercial fertilizers applied to the area.

Estimates of the nitrogen and salt loading rates from the various possible sources indicate that dairy wastes and fertilizers account for approximately 85% of the total nitrogen load to the area and dairy wastes are the largest contributor to the total salt load. Although fertilizers appear to contribute less nitrogen than dairy wastes, they may actually be just as important since actual fertilizer application rates commonly exceed recommended application rates by as much as 66%.

Nutrient analyses of water from 14 wells indicate that dairies are contributing organic nitrogen and phosphorus to the ground water. The organic nitrogen is commonly associated with high nitrate levels. Organic nitrogen and phosphorus were not detected in 2 wells located in crop fields which do not receive dairy wastes as a fertilizer.

A survey of animal waste management practices indicates that small dairies frequently contribute the largest nitrogen and salt loading per acre to the area. Nitrogen loading for individual dairies may be as high as 1,063 lbs N/acre/yr and salt loading as high as 12,355 lbs salt/acre/yr. These rates greatly exceed the needs of any crop.

Pesticide analyses were made on 15 wells located in or down ground water gradient from a variety of different crops. No pesticides were detected in any of these wells.

Research on the geology and hydrogeology show that there are 2 water bearing units which are used in the area for domestic, irrigation, livestock, and drainage purposes. Both of these water bearing units consist of unconsolidated sedimentary deposits of sand, silt, and clay. Water in the upper aquifer is separated from water in the lower, confined aquifer by the E-clay. Head differences between the 2 aquifers tend to move water from the upper aquifer down towards the lower aquifer.

Natural ground water levels in the upper aquifer are from 5 feet to 26 feet below the ground surface. Drainage wells in the area maintain levels at least 6 feet below the ground surface in many areas.

The ground water in the unconfined aquifer, and probably in the confined aquifer as well, flows in a westerly or southwesterly direction toward the San Joaquin River or the Merced River. The hydraulic gradient in the upper aquifer is about 3 to 7 feet per mile.

Factors important in determining whether or not nitrates will enter the ground water are soil types, ground water levels, well construction, application rates of fertilizers, irrigation water, and the type of crops grown and their nitrogen needs.

Soils in the Hilmar area are typically sandy, allowing rapid percolation of surface waters to the subsurface. In addition, the aerobic conditions common in sandy soils increase the nitrification of ammonia to nitrate. Nitrates are very soluble and move readily down to the ground water. The shallow ground water levels common in the area also minimize the effectiveness of nitrate removal processes which operate in the unsaturated zone.

Typical well construction methods in the area probably increase the movement of nitrates into both the upper and lower aquifers. Contaminated surface waters may reach the ground water through the annular space of wells completed without a sanitary surface seal, especially when the well is located near a source of nitrogen. Contaminated water in the upper aquifer may reach the lower, confined

aquifer through the annular space of deep wells. Deep wells in this area are typically perforated throughout the entire length of the casing, or, if only perforated below the confining layer, they have no seal separating the lower aquifer from the upper aquifer.

CONCLUSIONS AND RECOMMENDATIONS

Excessive nitrate levels are common in the Hilmar area ground water and can be directly related to the application of animal wastes to cropland in many instances. The use of commercial fertilizers on the golf course and a few crops in the area has also apparently resulted in excessive nitrate levels. The highest levels occur in the unconfined aquifer and are associated with dairies in almost all cases.

The salinity of the ground water is influenced predominantly by dairy operations. Salinity levels are not excessive now, but continuation of the current dairy waste management practices could increase the salinity levels in the future. Although most crops in the area are irrigated with water from the Tuolumne River and are not influenced by the ground water salinity, farmers must rely more on ground water in dry years to irrigate their crops. While septic tanks and poor well construction may cause local nitrate problems, these are insignificant in relation to the widespread use of animal wastes and commercial fertilizers. Proper management of the application of these nutrient sources to croplands can help to reduce nitrate levels in the ground water. Both commercial fertilizers and animal wastes should be applied at times and rates which are consistent with crop demands for nutrients. Soil or plant tissue analyses can be used to help

time the application of nutrients. Such analyses can be used to evaluate the nitrogen needs of the crop or the crop response to applied nitrogen.

Animal manures release nitrogen to the soil slowly and should be disced or otherwise incorporated into the soil well ahead of planting. The disposal of dairy wash water or wastewater should be timed to be consistent with the crop or soil needs for water as well as for nitrogen.

In order to maintain nitrate levels which are currently below 10 mg/l $\text{NO}_3\text{-N}$ it is recommended that the wastes from no more than 4 or 5 cows be applied per acre of cropland. In areas where the nitrate levels exceed 10 mg/l $\text{NO}_3\text{-N}$ a smaller number of cows per acre may be necessary to reduce the excessive levels. For dairies which have more than the recommended number of cows per acre of disposal, export of the excess wastes to an outside area could prevent excessive nitrates from reaching the ground water. Manures which are dried and processed could be shipped out of the area as organic fertilizers.

The use of wells in the unconfined aquifer to irrigate and recycle nitrogen through crops can also help to reduce already excessive nitrate levels. In addition, improving the efficiency of irrigation will help to prevent or reduce excessive nitrate levels. Excessive leaching volumes causes considerable leaching of nitrates, while lower drainage volumes contribute lesser amounts of nitrates to the ground water.

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In order to ensure that individual producers are complying with the recommendations given, each producer should be required to prepare a satisfactory plan for use or disposal of wastes.

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CALIFORNIA REGIONAL WATER QUALITY
CONTROL BOARD, Central Valley Region

Hilmar-Turlock

DAIRY ANIMAL WASTE DISPOSAL SURVEY

1. Business Name: _____
2. Operator's Name: _____
3. Mailing Address: _____
City _____ County _____ Zip _____
4. Are premises and land owned by operator?
(If leased, answer "No") _____
5. Is this a Grade A or Grade B dairy? _____
6.

Number of cattle	Dairy location	Other location
a. Milking cows	_____	_____
b. Dry cows	_____	_____
c. Bred heifers (15 to 30 months)	_____	_____
d. Calves (under 15 months)	_____	_____
7. What percentage of the total manure waste is handled:
 - a. Wet (using water as carrier to final disposal site)? _____
 - b. Dry (handled by mechanical means)? _____
8. Are the cows washed prior to milking by:
(Yes or No)
 - a. Sprinkler wash system? _____
 - b. Hose wash system? _____
 - c. Hand and bucket system? _____
 - d. Is this water reused for flushout? _____
Specify area flushed _____
 - e. How much water is used daily (gallons)? _____

Dairy Animal Waste Disposal Survey

(Yes or No)

9. Is a flushout system used on paved areas? _____
a. How much new water is used dairy (gallons)? _____
10. How is cow and barn wash water handled? _____
a. Holding Ponds? _____
 length (feet) _____
 width (feet) _____
 depth (feet) _____
 storage capacity (months) _____
b. Is a solids separator used? _____
c. Runs into owner's fields? _____
d. Is all wash water confined to property under control of operator? _____
11. Is wash water applied to cropland? _____
a. Is it applied by dilution in irrigation water? _____
b. If yes, over how much land (acres)? _____
c. Is it applied directly from wash down? _____
d. If yes, over how much land (acres)? _____
12. Does rainwater from corrals and other manured areas: _____
a. Go to holding ponds? _____
b. Stay in corral area? _____
c. Run onto land under operator's control? _____
d. Run off land under operator's control? _____
13. Is the corral area subject to periodic flooding from: _____
a. Rain _____

Dairy Animal Waste Disposal Survey

(Yes or No)

b. Stream or drainage ditch

14. In winter, how often is holding pond pumped?
(Check appropriate line.)

a. Once/week

b. 2-3/Month

c. Once/month

d. Once/3 Months

e. Not at all

In dry season, how often is holding pond pumped?

a. once/week

b. 2-3/month

c. Once/month

d. At each irrigation

15. How many cropland acres are used or available for dry manure disposal?

a. Owned or leased at this location

b. Owned or leased at other location

c. Is other land available?

d. What crops are grown?

16. How much dry manure is hauled off, sold or given away annually from this dairy?

a. Measurement in cubic yards, or

b. Measurement in tons

Dairy Animal Waste Disposal Survey

HILMAR-TURLOCK
ANIMAL WASTE DISPOSAL SURVEY
FOR
POULTRY OPERATIONS

1. Business Name: _____
2. Operator's Name: _____
3. Mailing Address: _____
City _____ County _____ Zip _____
4. Location and/or address: (if different than above) _____

Is this ranch presently being operated? YES _____ NO _____

6. Type of operation and numbers: (at any one time)
 - a. Fryers _____ Number _____
 - b. Layers _____ Number _____
 - c. Others _____ Number _____Type of housing: (a) cages _____ (b) litter _____
8. Is water used for manure removal? YES _____ NO _____
9. If water is used for flushout, where does it go?
 - a. Holding ponds _____
 - b. Stays on property under operator's control _____
 - c. Leaves property under operator's control _____
10. How often is manure and/or litter removed from housing? _____
_____ (daily, weekly, monthly, annually, etc.)
11. How often is manure removed from the ranch? (daily, monthly, annually)

Dairy Animal Waste Disposal Survey

17. From whom does the operator and/or owner receive technical assistance for the management of the animal waste?
-

SALT LOADING

- A. ____ total AU (from 1.A.)
- B. Total lbs salt excreted/day:
 (____ total AU)(2.2 lbs* salt excreted/cow/day) = ____ total lbs salt excreted/day
- C. Lbs salt retained at dairy/day:
 ____ total lbs salt excreted/day - (____ yd³ hauled off/yr)(0.075**) = ____ lbs salt retained/day
- D. Total lbs salt/acre/day:
 ____ lbs salt retained/day/____ acres for disposal = ____ total lbs salt/acre/day
- L. Total lbs salt/acre/yr:
 ____ total lbs salt/acre/day x 365 days/yr = ____ total lbs salt/acre/yr

* "In California, a 1400 pound dairy cow eliminates a combined weight of salts of about 2.2 lbs/day", from *Dairy Manure Utilization & Field Application Rates*, by J.L. Meyers, R.S. Rauschkolb, E. Olson

$$** \frac{\text{yd}^3/\text{yr}}{365 \text{ days/yr}} \cdot \frac{27 \text{ ft}^3}{\text{yd}^3} \cdot \frac{14.4 \text{ lbs}}{\text{ft}^3} (0.07) = 0.75 \text{ lb salt/day}$$

7% of dry solids are salts (from *Dairy Manure Utilization & Field Application Rates*, page 6)

14.4 lb/ft³ = dry density of dairy manure (see ** for N loading)

1. NITROGEN LOADING CALCULATIONS FOR DAIRY OPERATIONS

A. Number of Animal Units* (AU):

Milking Cows _____ x 1 = _____ AU

Dry Cows _____ x 0.75 = _____ AU

Calves _____ x 0.40 = _____ AU

B. Lbs N excreted/day

$$(A \text{ total AU}) (0.4 \text{ lb N/cow/day}) = B \text{ lbs N excreted/day}$$

C. Lbs N retained on dairy/day - wet

$$(B \text{ lbs N excreted/day})(\% \text{ wet handling})(\% \text{ N retention}^{**} \text{ in holding ponds}) =$$

C lbs N retained on dairy/day - wet

D. Lbs N retained on dairy/day - dry

$$[(B \text{ lbs N excreted/day})(\% \text{ dry handling})(\text{yd}^3 \text{ hauled away/yr})$$

$$(.027^{***})](.50^{****})(.75^{*****}) = D \text{ lbs N retained on dairy/day - dry}$$

E. Total N retained on dairy/day:

$$C \text{ lbs N - wet} + D \text{ lbs N - dry} = E \text{ total lbs N retained/day}$$

F. Lbs N/acre retained on dairy/day:

$$E \text{ lbs N retained/day/} \quad \text{acres for disposal} = F \text{ lbs N/acre/day}$$

G. Lbs N/acre retained on dairy/yr:

$$F \text{ lbs N/acre/day} \times 365 \text{ days/yr} = \text{ lbs N/acre/yr}$$

*

~~**70% of N retained for a holding period of 30 days or less, 50% retention of N for holding periods of 60 days or more (J. L. Meyer, R. S. Rauschkilb, and E. Olson, ¹⁹⁷⁵, Dairy Manure Utilization and Field Application, p. 5.)~~

$$*** \frac{\text{yd}^3/\text{yr}}{365 \text{ day/yr}} \frac{27 \text{ ft}^3}{\text{yd}^3} \frac{14.4 \text{ lb}}{\text{ft}^3} (.0256 \text{ N}) = .027 \text{ lb N/day,}$$

where 14.4 lb/ft^3 = dry density of dairy manure (from "Farm Animal Manure", p. 22) and 2.56% of dry weight is N ("Farm Animal Manure", p. 16) (Azevedo, 1974).

(Azevedo, 1974)

****Assume a 50% loss of N in corral manure (~~"Farm Animal Manure", p. 33)~~)

**** Decay constant for 1st year = 0.40, 2nd year = 0.15, 3rd year = 0.10, 4th year = 0.10 = 0.75 for cumulative 4 year period (Gilbertson et al, 1979)

2. SALT LOADING CALCULATIONS FOR DAIRY OPERATIONS

A. total AU (from 1.A.)

B. Total lbs salt excreted/day:

(total AU)(2.2 lbs* salt excreted/cow/day)= total lbs salt excreted/day

C. Lbs salt retained at dairy/day:

 total lbs salt excreted/day - (yd³ hauled off/yr)(0.075**)=
 lbs salt retained/day

D. Total lbs salt/acre/day:

 lbs salt retained/day / acres for disposal = total lbs salt/acre/day

E. Total lbs salt/acre/yr:

 total lbs salt/acre/day x 365 days/yr = total lbs salt/acre/yr

*"In California, a 1400 pound dairy cow eliminates a combined weight of salts of about 2.2 lbs/day", from ~~Dairy Manure Utilization & Field Application Rates~~, by J. L. (Meyers, R. S. Rauschkolb, E. Olson, 1975).

** $\frac{\text{yd}^3/\text{yr}}{365 \text{ days/yr}} \cdot \frac{27 \text{ ft}^3}{\text{yd}^3} \cdot \frac{14.4 \text{ lbs}}{\text{ft}^3} (0.07) = 0.75 \text{ lb salt/day}$

7% of dry solids are salts (from ~~Dairy Manure Utilization & Field Application Rates~~, page 6) (Meyers, R. S. Rauschkolb, E. Olson, 1975)

14.4 lb/ft³ = dry density of dairy manure (see ** for N-loading)

(Meyers, Rauschkolb, Olson, 1975)

Evaluation of Mass Balance

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Based on the discussion above, the contribution of nitrogen and salts from the various sources are as follows:

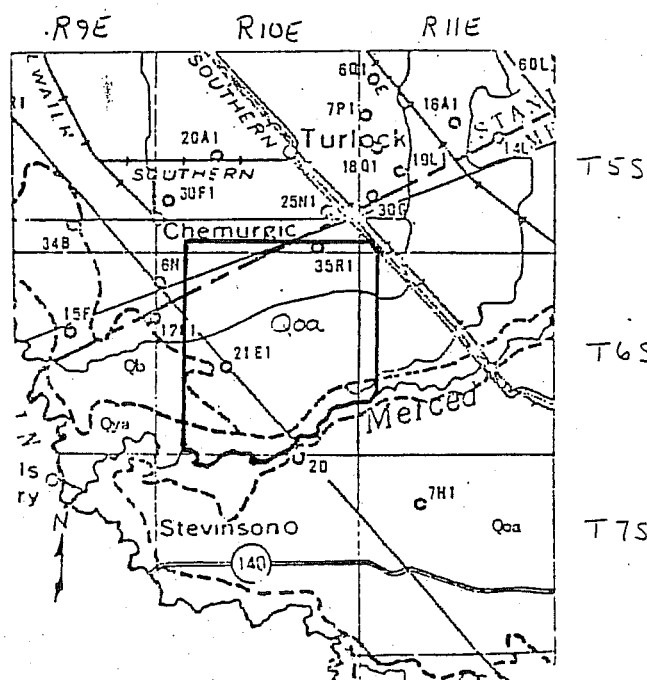
Source	Annual Nitrogen Loading (tons N/yr)	Percent N Loading	Annual Salt Loading (tons salt/yr)	Percent Salt Loading
Animal Wastes	446	52	10,157	50
Commercial Fertilizers	288	33	2,818	14
Nitrogen Fixation	50	6	—	—
Irrigation Water	44	5	7,073	35
Domestic Wastes	33	4	179	1
Totals	861	100	20,227	100

The percentages above indicate that animal wastes and fertilizers account for approximately 85 percent of the total nitrogen loading. Approximately 446 tons of nitrogen from animal wastes are applied over 10,241 acres annually, for an average loading rate of 87 lbs N/acre-yr. The average nitrogen loading rate for commercial fertilizers is 63 lbs N/acre-yr (288 tons N/yr applied over 9,101 acres). The actual loading rate for fertilizers may be higher due to individual application rates which commonly exceed the recommended rates. Although the loading rates for these 2 sources are very rough estimates, it is apparent that the application of animal wastes and commercial fertilizers are the predominant sources of nitrogen in this area.

The application of animal wastes and irrigation water ^{to cropland} accounts for about 85 percent of the total salt loading. 10,157 ton salt/yr applied over 10,241 acres is an approximate average salt loading of 1,984 lbs salt/acre-yr due to animal

Figure 3. Geologic Map of the Hilmar and Surrounding Areas

DRAFT



From Page and Balding, 1973.

EXPLANATION

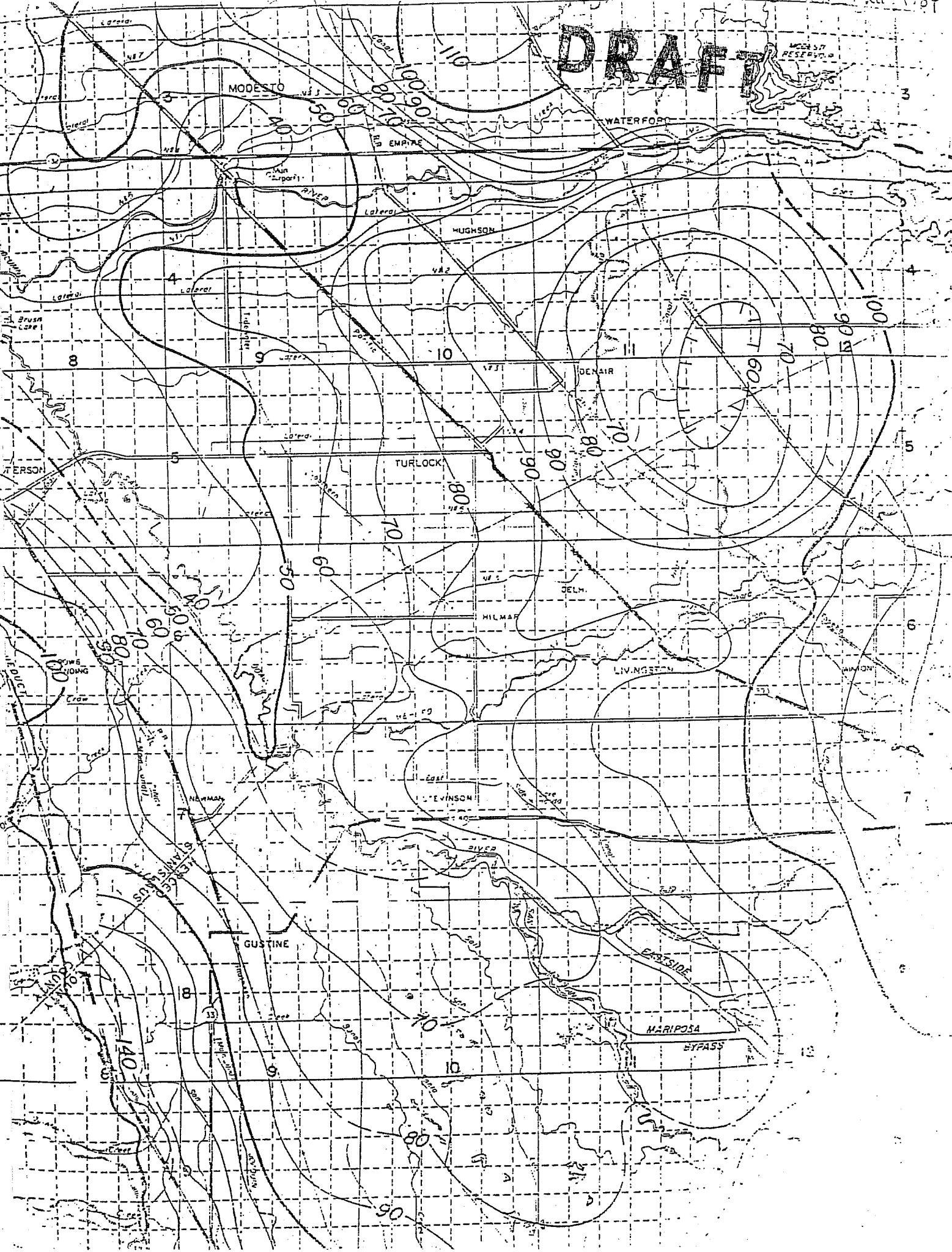
Unconsolidated Deposits

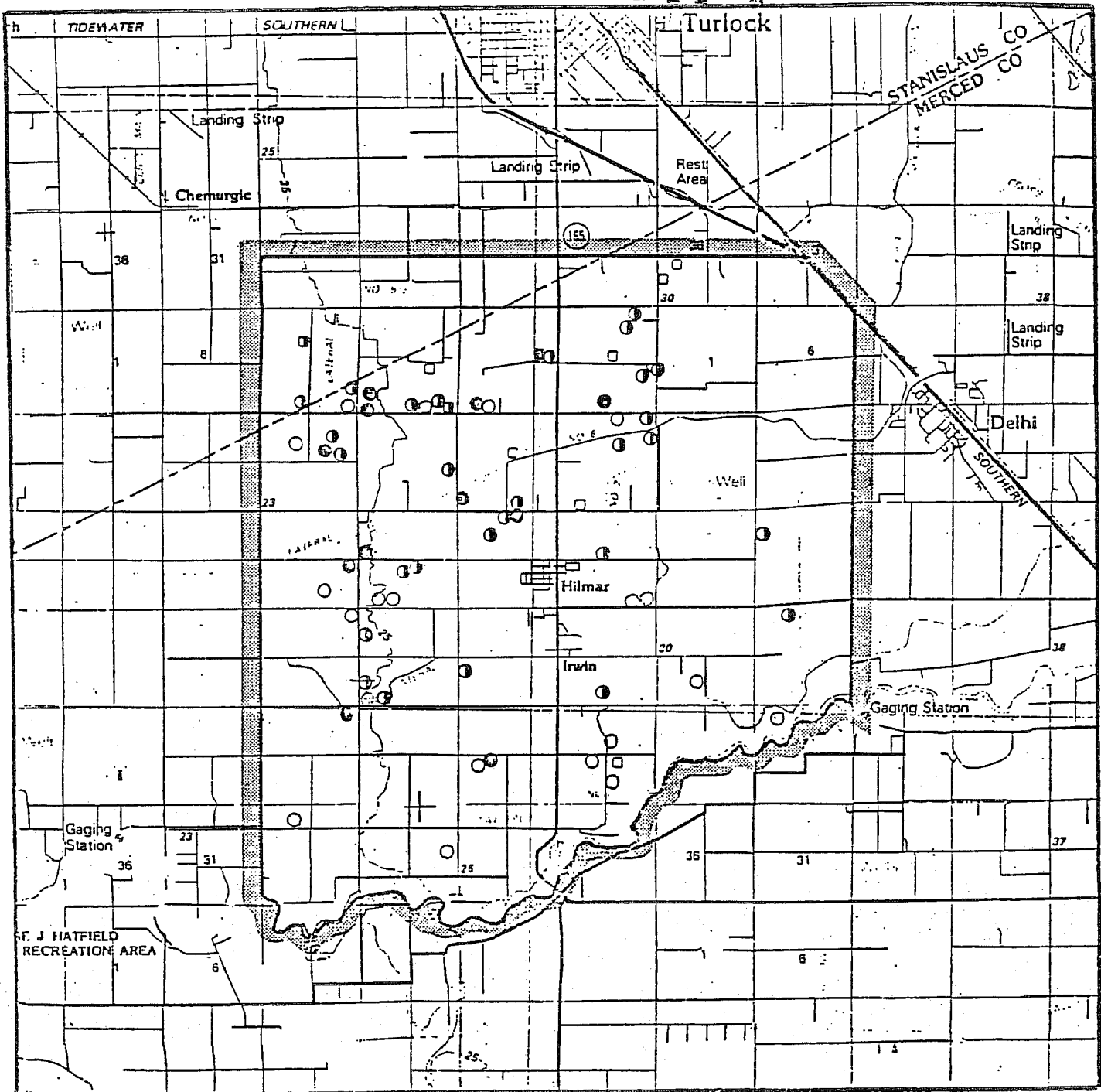
Pleistocene and Holocene?	{	Holocene	{	Qb	Qya	Quaternary
				Flood-basin deposits	Younger alluvium	
				Qoa	Older alluvium	

0 5 MILES

Geologic Contact

DRAFT





Base map from U.S. Geological Survey 1:100000 Merced, California, 1983.

EXPLANATION

Nitrate concentrations are as indicated below.
 Circles indicate wells completed in the unconfined aquifer. Squares indicate wells completed in the confined aquifer.

- <10 mg/l $\text{NO}_3\text{-N}$
- ◻ 10-19 mg/l $\text{NO}_3\text{-N}$
- ◼ ≥20 mg/l $\text{NO}_3\text{-N}$

SCALE

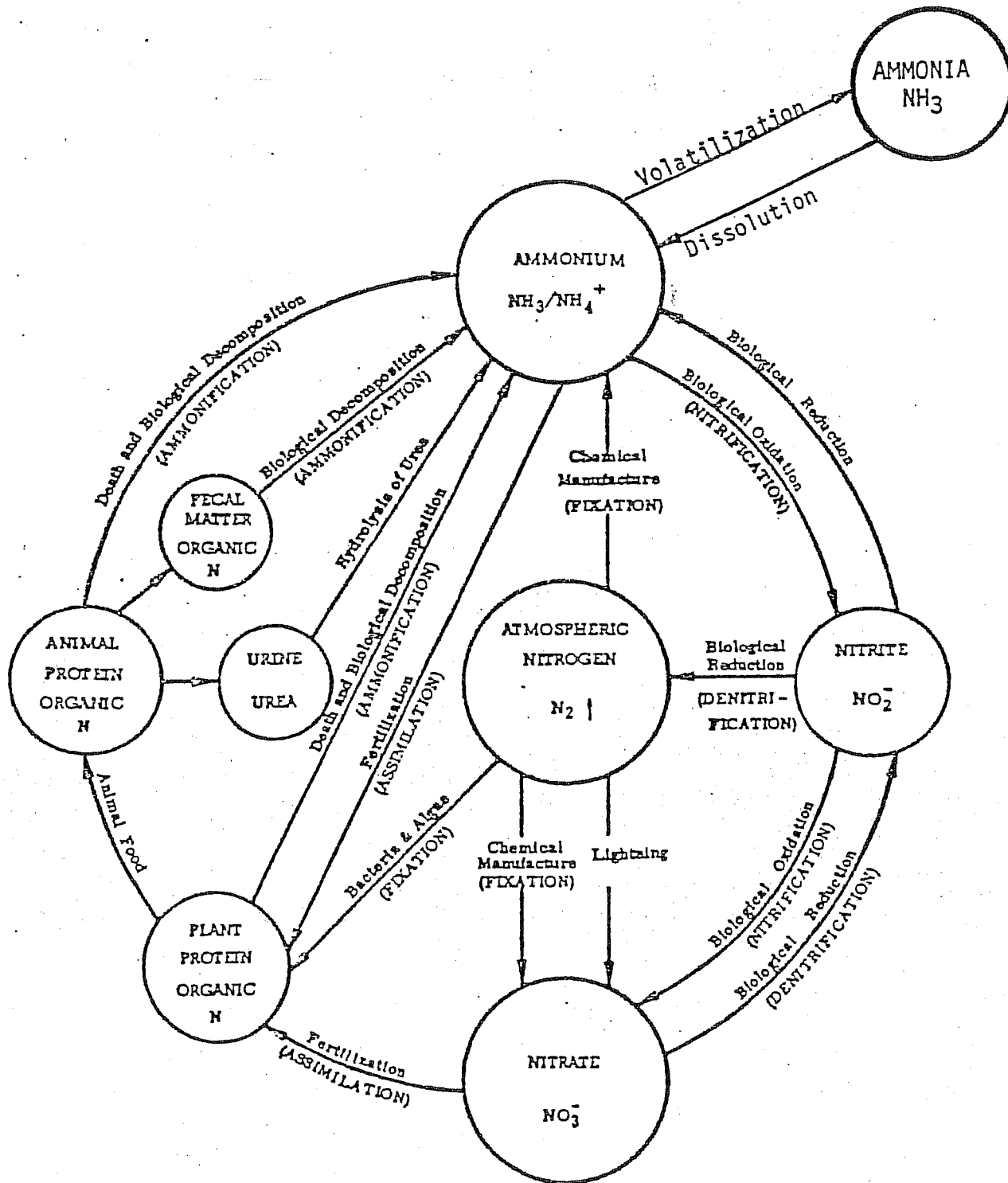
0 1 2 Miles

Figure 6. Hilmar Ground Water Nitrate Concentrations, June 1986

Schematic Representation of the Nitrogen Cycle

(EPA, 1975)

DRAFT



from U.S. E.P.A., Nitrogen Control, October 1975.

Figure 7
X

Table 1. Generalized Geologic Section of the Hilmar Area (modified from Page and Zelding, 1973).

System and series	Geologic unit	Lithologic character	Maximum thickness (feet)	Water-bearing character
Unconsolidated Deposits				
QUATERNARY	Holocene	Flood-basin deposits	100	Small hydraulic conductivities and small yields to wells.
		Younger alluvium	100	Moderate to large hydraulic conductivities, where saturated yields moderate quantities to wells. Unconfined.
	Pleistocene and Holocene?	Older alluvium	300	Moderate to large hydraulic conductivities; yield to wells as large as 308 cfm. Specific capacity usually greater than 53 ft/min in northern two-thirds of the study area and less than 53 ft/min in the southern third of the study area.
	Pleistocene	Lacustrine and marsh deposits	60	Confining bed, very small hydraulic conductivities.
TEERTARY AND QUATERNARY?	Pliocene and Pleistocene?	Continental deposits	400	Moderate to large hydraulic conductivities; yield to wells as large as 281 cfm. Maximum specific capacity are 35 ft/min.
Consolidated Rocks				
Tertiary	Miocene and Pliocene	Mohrton Formation	1200 at Valley center	Small to moderate hydraulic conductivities. Average yield of about 134 cfm and a horizontal transmissibility of about 9,100 ft ² /day.

Table 2. Parameters Analyzed with Corresponding Laboratory and Analytical Methods

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Parameter	Laboratory *	Analytical Method	Method Description **
Ca	Anteb Analytical Laboratory	EPA 7140	AA, Direct Aspiration
Mg	"	EPA 7450	"
Na	"	EPA 7770	"
K	"	EPA 7610	"
Cl	"	Standard Method 429	Ion Chromatography
SO ₄	"	Standard Method 429	"
Carbonate Alkalinity	"	EPA 310.1	Titrimetric (pH 4.5)
Bicarbonate Alkalinity	"	EPA 310.1	"
Total Hardness	"	EPA 130.2	Titrimetric, EDTA
Total Dissolved Solids	"	EPA 160.1	Gravimetric
Conductance	"	EPA 120.1	Specific Conductance
pH	"	EPA 9040	Electrometric
Boron	"	—	Azomethine-H
NO ₃ -N	"	Standard Method 429	Ion Chromatography
TKN	"	Standard Method 420-A	Macro-Kjeldahl
NH ₃ -N	"	Standard Method 420-A	"
Orthophosphates	"	Standard Method 424-F	Ascorbic Acid
Total Phosphates	"	Standard Method 424-F, 424-DM	Ascorbic Acid, Persulfate Digest
Organochlorine Pesticides & PCB's	CAL / CWL	EPA 608 / EPA 608	GC / GC
Organophosphorus Pesticides	CAL / CWL	EPA 614 / EPA 622 & 8140	GC-FPD or NPD / GC-FPD or N
Carbamate and Urea Pesticides	CAL / CWL	EPA 632 / EPA 630 & 632	HPLC-UV / Colorimetric & HPLC-UV
Triazine Pesticides	CAL / CWL	EPA 619 / EPA 619	GC-NPD / GC-NPD
DBCP	CAL	—	GC-NPD and GC-ECD

CAL - California Analytical Laboratory, Inc.

** AA - atomic absorption

UV - ultraviolet

CWL - California Water Labs, Inc.

GC - gas chromatography

HPLC - high performance

FPD - flame photometric

liquid chromatography

NPD - nitrogen phosphorus

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4: % Difference between Original and Duplicate Sample Analyses (% Difference = $\frac{|Duplicate - Original|}{Original} \times 100$)

Parameter	Number of Duplicate Samples	Range of % Difference	Average % Difference
Ca	8	0.0-23.6	9.1
Mg	8	0.0-16.0	7.1
Na	8	0.0-134	17.6
K	10	0.0-39	4.2
Cu	7	0.0-45.5	13.6
SO ₄	7	0.0-12.1	4.7
Carb. Alk.	8	0.0-100	37.5
Bicarb. Alk.	8	9.7-170	37.5
Total Hardness	8	0.0-50	14.2
TDS	7	1.9-15.2	7.2
Spec. Cond.	7	0.0-2.8	0.8
pH	8	1.3-4.8	2.9
B	8	0.0-100	29.0
NO ₃ -N	19	0.0-62.5	12.7
TKN	2	0.0-0.0	0.0
NH ₃ -N	1	0.0	0.0
Orthophosphate	2	50.0-333	192
Total Phosphate	2	29.0-64.0	46.0
Organochlorine Pesticides PCBs	2	0.0-0.0	0.0
Organophosphorus Pesticides	1	0.0	0.0
Carbamate & Urea Pesticides	1	0.0	0.0
Triazine Pesticides	1	0.0	0.0
DBCP	1	0.0	0.0

0.01 = detection limit

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Chemical Standards Results

	Standard #1 (mg/l)		Standard #2 (mg/l)		Standard #3 (mg/l)		Standard #4 (mg/l)		Standard #5 (mg/l)	
	Standard	Lab	Standard	Lab	Standard	Lab	Standard	Lab	Standard	Lab
meten										
2	28.8	34	27.7	31	13.5	18	14.2	16	30.9	33
7	24.4	26	18.7	19	19.6	18	12.1	11	13.7	12
10	139	120	96	80	98	78	113	95	64.0	50
10	120	130	48.3	110	80	60	59.5	66	93.0	100
14	260	260	183	190	181	190	221	74	114	110
aspartic	36.3	80	22.2	0	29.8	84	17.8	30	25.1	20
	202	2.2	0.88	0.95	1.49	1.2	1.32	1.3	0.915	0.49
23-N*	8.7	7.0	2.9	2.8	6.0	4.6	0.77	0.68	4.09	3.0
3*	38.7	31.0	12.8	12.4	26.5	20.4	3.4	3.0	18.1	13.3

ate standards were submitted to the laboratory in April of 1987.

Table 6:

Relative Standard Deviation of Mineral Standards

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	Standard #1	$x_1 - \bar{x}_1$	Standard #2	$x_2 - \bar{x}_2$	Standard #3	$x_3 - \bar{x}_3$	Standard #4	$x_4 - \bar{x}_4$	Standard #5	$x_5 - \bar{x}_5$	Relative Error
L	$x_1 = 1$ $\bar{x}_1 = 1.18$	-0.18	$x_2 = 1$ $\bar{x}_2 = 1.12$	-0.12	$x_3 = 1$ $\bar{x}_3 = 1.33$	-0.33	$x_4 = 1$ $\bar{x}_4 = 1.13$	-0.13	$x_5 = 1$ $\bar{x}_5 = 1.07$	-0.07	0.21
1	$x_1 = 1$ $\bar{x}_1 = 1.07$	-0.07	$x_2 = 1$ $\bar{x}_2 = 1.02$	-0.02	$x_3 = 1$ $\bar{x}_3 = 0.92$	0.08	$x_4 = 1$ $\bar{x}_4 = 0.91$	0.09	$x_5 = 1$ $\bar{x}_5 = 0.88$	0.12	0.09
2	$x_1 = 1$ $\bar{x}_1 = 0.86$	0.14	$x_2 = 1$ $\bar{x}_2 = 0.83$	0.17	$x_3 = 1$ $\bar{x}_3 = 0.20$	0.20	$x_4 = 1$ $\bar{x}_4 = 0.84$	0.16	$x_5 = 1$ $\bar{x}_5 = 0.78$	0.22	0.20
3	$x_1 = 1$ $\bar{x}_1 = 1.08$	-0.08	$x_2 = 1$ $\bar{x}_2 = 2.28$	-1.28	$x_3 = 1$ $\bar{x}_3 = 0.75$	0.25	$x_4 = 1$ $\bar{x}_4 = 1.11$	-0.11	$x_5 = 1$ $\bar{x}_5 = 1.08$	-0.08	0.66
4	$x_1 = 1$ $\bar{x}_1 = 1$	0.00	$x_2 = 1$ $\bar{x}_2 = 1.04$	-0.04	$x_3 = 1$ $\bar{x}_3 = 1.05$	-0.05	$x_4 = 1$ $\bar{x}_4 = 0.33$	0.67	$x_5 = 1$ $\bar{x}_5 = 0.96$	0.04	0.34
Carbonate	$x_1 = 1$ $\bar{x}_1 = 2.20$	-1.20	$x_2 = 1$ $\bar{x}_2 = 0$	1.0	$x_3 = 1$ $\bar{x}_3 = 2.82$	-1.82	$x_4 = 1$ $\bar{x}_4 = 1.69$	-0.69	$x_5 = 1$ $\bar{x}_5 = 0.80$	0.20	1.25
5	$x_1 = 1$ $\bar{x}_1 = 1.09$	-0.09	$x_2 = 1$ $\bar{x}_2 = 1.08$	-0.08	$x_3 = 1$ $\bar{x}_3 = 0.81$	0.19	$x_4 = 1$ $\bar{x}_4 = 0.98$	0.02	$x_5 = 1$ $\bar{x}_5 = 0.54$	0.46	0.26
-N	$x_1 = 1$ $\bar{x}_1 = 0.80$	0.20	$x_2 = 1$ $\bar{x}_2 = 0.97$	0.03	$x_3 = 1$ $\bar{x}_3 = 0.77$	0.23	$x_4 = 1$ $\bar{x}_4 = 0.88$	0.12	$x_5 = 1$ $\bar{x}_5 = 0.73$	0.27	0.21

Relative Error ($\frac{\sigma}{\bar{x}}$)

*

$$\sigma = \sqrt{\frac{\sum (x_i - \bar{x})^2}{(n-1)}}$$

Ca

0.09

Mg

0.04

Na

0.09

Cl

0.30

SO₄

0.15

HCO₃

0.56

B

0.12

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Table 44. Hilmar Surface Water Mineral Analyses

SITE NUMBER	SITE DESCRIPTION	SAMPLE DATE	Ca mg/l	Mg mg/l	H ₂ mg/l	K mg/l	Cl mg/l	SO ₄ mg/l	Carb		Bicarb		Total Hardness mg/l	TDS mg/l	EC mg/l	pH
									As CaCO ₃ mg/l	AlE mg/l	As CaCO ₃ mg/l	B mg/l				
6S 10E 090	Dairy Pond	860618	83	33	34	171	59	35	0	0	150	0.54	340	680	1800	8.0
6S 10E 10H	Irr Canal	860618	8.6	2.6	3.8	1.0	3	5	0	0	30	0.02	34	53	100	7.6
6S 10E 16P	Dairy Pond	860618	140	95	250	520	370	32	0	0	370	1.2	600	2600	5400	7.8
6S 10E 22A	Irr Canal	860618							0.99							
6S 10F 27J	Irr Canal	860618	2.0	2.2	2.6	0.99	5	5	0.46	0	30	0.02	30	92	110	7.7

Table 8. Mineral Analysis of Ground Water in the Unconfined Aquifer.

[illegible]

11/15/11 11:51 AM

[illegible]

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Table 8.—Nictal activity of ground water in the Ogouffine; July

[illegible]

* A duplicate of the above sample

11. These samples were taken during the initial stages of purging, before three casing cluses of water were purged from the well.

Table 9. Mineral Analysis of α and β in the Confined Geofiber.[illegible]

* A duplicate of the above sample

These ^{analysis} results probably represent composite water from both the confined and unconfined aquifers

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TABLE 10. Land Use versus Nitrate Concentrations for all Wells Sampled

LAND USE AT WELL SITE	TOTAL NUMBER OF WELLS SAMPLED	NUMBER OF WELLS WITH $\geq 10 \text{ mg/l NO}_3\text{-N}$	PERCENT OF WELLS $\geq 10 \text{ mg/l NO}_3\text{-N}$	LAND USE SURROUNDING WELLS $\geq 10 \text{ mg/l NO}_3\text{-N}$
Dairy	28	16	57	13 of the 16 are down ground water gradient from corn/grain fields, 3 are down gradient from other dairies, 2 are down gradient from sudan, 2 from vineyards, & 1 from an almond orchard.
Corn/oats/grain	14	10	71	All of the 10 are either within 200 feet of a dairy or within 100 feet down gradient of a dairy.
Orchards	10	4	40	2 of the 4 wells are within 1250 feet down ground water gradient from a dairy and one is within 100 feet north of a dairy. One is down gradient from natural vegetation.
Alfalfa	5	3	60	2 of the 3 wells are within 500 feet down gradient of a dairy, 1 is 100 feet NW of a dairy pond, and 100' W of corn/oats.
Urban	5	4	80	3 of the 4 are down gradient of the golf course. The 4th is 100 feet north of the golf course.
Farmstead	2	2	100	Both of these wells are down ground water gradient from corn, oats and/or grain.
Sudan	3	0	0	
Mixed Pasture	1	1	100	This well is on property owned by a dairy operator and which probably receives dairy wastes as a fertilizer.
Poultry	1	0	0	

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TABLE 10. Land Use Versus Nitrate Concentration for all Wells Sampled

LAND USE AT WELL SITE	TOTAL NUMBER OF WELLS SAMPLED	NUMBER OF WELLS WITH $\geq 10 \text{ mg/L NO}_3\text{-N}$	PERCENT OF WELLS $\geq 10 \text{ mg/L NO}_3\text{-N}$	LAND USE SURROUNDING WELLS $\geq 10 \text{ mg/L NO}_3\text{-N}$
Dairy	28	16	57	13 of the 16 are down gradient water gradient from corn/grain fields, 3 are down gradient from other dairies, 2 are down gradient from sudan, 2 from vineyards, & 1 from an almond orchard.
Corn/ots/grain	14	10	71	All of the 10 are either within 300 feet of a dairy or within 100 feet down gradient of a dairy.
Orchards	10	4	40	2 of the 4 wells are within 1250 feet down gradient water gradient from a dairy and one is within 100 feet north of a dairy. One is down gradient from natural vegetation.
Alfalfa	5	3	60	2 of the 3 wells are within 500 feet down gradient of a dairy, 1 is 100 feet NW of a dairy pond, and 100' W of corn/ots.
Urban	5	4	80	3 of the 4 are down gradient of the golf course. The 4th is 100 feet north of the golf course.
Farmstead	2	2	100	Both of these wells are down ground water gradient from corn,ots and/or grain.
Sudan	3	0	0	
Mixed Pasture	1	1	100	This well is on property owned by a dairy operator and which probably receives dairy wastes as a fertilizer.
Poultry	1	0	0	

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Table 11. Nitrogen and Salinity versus Depth in the Unconfined Aquifer

Well Depth*	Number	Mean	Range of	Average EC	Range of EC
(ft)	of Wells	Average $\text{NO}_3\text{-N}$ (mg/l)	$\text{NO}_3\text{-N}$ (mg/l)	($\mu\text{mhos/cm}$)	($\mu\text{mhos/cm}$)
0-50	6	17	.05-31	617	370-960
51-100	27	13	<0.01-35	657	350-1200
101-150	12	11	<1-21	696	310-1100
151-200	4	11	0.06-24	918	720-1200

* Well depth is considered to be the bottom of the perforation interval or the bottom of the casing if the perforation interval is not known.

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make title more descriptive

12
→ Table 7. Hilmar Pesticide Analyses

Pesticide analyses for selected ground water samples taken from operating wells in the Hilmar area.

WELL NUMBER	SAMPLE DATE	ORGANOCHLORINE PESTICIDES & PCB's	ORGANOPHOSPHOROUS PESTICIDES	CARBAMATE & UREA PESTICIDES	TRIAZINE PESTICIDES	THIOCARBAMATE COMPOUNDS	DBCP (ug/l)	LABORATORY*
5S 10E 36M2	860617	ND	ND	ND	ND	ND		CWL
6S 10E 02A1	860619	ND	ND	ND	ND	ND	<0.01	CWL
6S 10E 02J1	860618	ND	ND	ND	ND	ND	<0.01	CWL
6S 10E 02J2	860617	ND	ND	ND	ND	ND	<0.01	CWL
6S 10E 11A2	860625	ND	ND	ND	ND	ND	<0.01	CWL
6S 10E 11B	860617	ND	ND	ND	ND	ND		CWL
6S 10E 17A	860617	ND	ND	ND	ND	ND		CWL
6S 10E 20A	860626	ND	ND	ND	ND	ND		CAL
6S 10E 21N3	860618	ND	ND	ND	ND	ND	<0.01	CWL
6S 10E 24L	860625	ND	ND	ND	ND	ND	<0.01	CWL
	860625**	ND	ND	ND	ND	ND		CWL
	860625	ND	ND	ND	ND	ND		CAL
6S 10E 26G	860618	ND	ND	ND	ND	ND		CWL
6S 10E 26L	860626	ND	ND	ND	ND	ND	<0.01	CWL
6S 10E 27L2	860626	ND	ND	ND	ND	ND	<0.01	CWL
6S 11E 19C	860626	ND	ND	ND	ND	ND	<0.01	CWL
	860626**	ND	ND	ND	ND	ND		CWL
	860626	ND	ND	ND	ND	ND		CAL
6S 11E 30C	860619	ND	ND	ND	ND	ND		CWL

* LABORATORY: CWL = California Water Lab

CAL = California Analytical Laboratories

See Appendix C for the analyses performed by the 2 different labs

All DBCP analyses were performed by CAL

** A duplicate of the above sample

Blank spaces indicate that no analysis was performed

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Table 13. Fertilizer Use Patterns in the Hilmar Area¹

	Recommended Fertilizer Application Rate	Types of Fertilizers	Estimated Amount of Each Fertilizer Used ²	Estimated Total Salt Contribution from All Fertilizers ³
CROP	(lbs N/acre-yr)	Commonly Used	(lbs/acre-yr)	(lbs)
Corn	200	Aqua Ammonia	250	
		Ammonium Sulfate	238	
		UAN-32	156	
		15-15-15	333	977
Sudan	60	Ammonium Sulfate	143	
		15-15-15	200	343
Dry Beans (Pink, Red, & Limas)	30	12-12-12	250	250
Alfalfa	30	11-52	273	273
Native, Mixed Pasture	55	Ammonium Sulfate	262	262
Deciduous Fruits & Nuts	150	Ammonium Sulfate	238	
		UAN-32	156	
		15-15-15	333	727
		Ammonium Sulfate	79	
Vineyards	50	Urea	36	
		UAN-32	52	167
		12-12-12	417	
Sweet Potatoes	100	Anhydrous Ammonia	61	478
Melons, Squash Cucumbers	100	12-12-12	417	
		Anhydrous Ammonia	61	478
Oats	65	16-20-0	203	
		Ammonium Sulfate	155	358
Lawn	200	16-6-8	625	
		21-7-14	476	1,101

¹Information on fertilizers used obtained from the Stanislaus Farm Supply and the UCD Cooperative Extension Office in Merced County.²Based on the amount of fertilizer needed to supply the recommended lbs N/acre-yr. Where different

Titles should be descriptive

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13 Nutrient concentrations in selected groundwater samples
 taken from operating wells in the Hilmar area of California
 Table 2. ~~Hilmar Ground Water Nutrient Analyses~~

WELL NUMBER	SAMPLE DATE	TKN mg/l as N	Ortho- phosphates mg/l	Total NO3-N mg/l	NH3-N mg/l	K mg/l	Total Phosphates mg/l as P	Land Use at Well Site	Well Depth (ft)
6S 10E 04N2	860617	0.78	0.05	17	<0.02	3.2	0.15	Dairy	20
	861015	0.3	0.06	36		2.4	0.09		
6S 10E 05R	861015		0.05	7.7		4.7	0.08	Dairy	155
6S 10E 08F	860617	0.67	0.03	9.0	<0.02	3.0	0.26	Dairy	110
6S 10E 08H2	861015	0.62		1.8				Corn	55
6S 10E 10N	861015		0.03	23		5.6	0.06	Dairy	20
6S 10E 15B2	860618	0.34	0.07	14	<0.02	1.8	0.11	Dairy	95
	861015	0.2	0.04	14		3.3	0.22		
	861015*	0.2	0.02	15		2.3	0.08		
6S 10E 16E1	860619	0.73	0.17	24	<0.02	1.5	0.23	Dairy	113
	861015	0.7	0.19	21		2.1	0.21		
6S 10E 16P1	860618	0.17	0.09	<0.01	<0.02	3.0	0.19	Dairy	129
	861015	0.1	0.08	<1		3.2	0.13		
6S 10E 16P2	860617	0.11	0.16	0.02	<0.02	2.6	0.19	Dairy	111
	861015	0.6	0.14	<1		3.0	0.16		
6S 10E 17J	860619	0.84	0.90	24	<0.02	2.7	0.90	Alfalfa	200
	861015	1.2	0.89	23		3.4	0.89		
	861015**	<0.1	0.87	21		3.5	0.91		
6S 10E 21N2	861015**	0.8	0.85	21		3.4	0.91	Corn, Oats	20
	860617	0.39	0.05	12	<0.02	1.8	0.21		
	861015		0.04	9		2.0	0.13		
6S 10E 21N3	860618	0.50	0.07	15	<0.02	1.7	0.13	Pasture	112
	861015		0.05	15		1.9	0.11		
6S 10E 26G	860618	0.05	0.18	0.05	<0.02	2.3	0.18	Grain	50
6S 10E 26L	860626	<0.06		2.1	<0.02			Almonds	112

* A duplicate of the above sample

** Sample collected 5 minutes after the above sample

*** Well depth is considered to be the bottom of the perforation interval or the bottom of the casing if the perforation interval is not known
 Blank spaces indicate that no analyses were performed

Nutrients: TKN = Total Kjeldahl Nitrogen
 NO3-N = Nitrate as Nitrogen
 NH3-N = Ammonia as Nitrogen
 K = Potassium

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Table 14. Most Common Sources of Fertilizer Nitrogen in Merced County during 1986.

Grade	Nitrogen Source	Tons N/year	Percent of Total Annual N
32-00-00	Urea Ammonium Nitrate	2,523	40.7
20-00-0A	Aqua Ammonia	896	14.5
10-03-03		541	8.7
21-00-00	Ammonium Sulfate	507	8.2
46-00-00	Urea	471	7.6

from California Department of Food and Agriculture, Fertilizing Materials, Tonnage Report,
October-November-December 1986.

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14.
Table 4. Hilmar Surface Water Nutrient Analyses

SITE NUMBER	SITE DESCRIPTION	SAMPLE DATE	TKN mg/l as N	Ortho- phosphates mg/l	Total NO3-N mg/l	NH3-N mg/l	K mg/l	Total Phosphates mg/l as P
6S 10E 10H	Irr Canal	860618	0.39	0.05	1.7	<0.02	1.1	0.12
6S 10 09Q	Dairy Pond	860618	0.41	22	0.25	<0.02	130	180
6S 10E 16P	Dairy Pond	860618	310	84	0.10	240	420	110

Nutrients: TKN = Total Kjeldahl Nitrogen
 NO3-N = Nitrate as Nitrogen
 NH3-N = Ammonia as Nitrogen
 K = Potassium

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Table 15. Acres of Crops Fertilized with Dairy Wastes

Crop	Acres (from 47 surveyed dairies)	Percent of Total Acres	Estimated Additional Acreage Receiving Animal Wastes at 15 dairies not surveyed *	Estimated Total Acreage
Corn (oats)	5196	73.0	1658	6854
Corn	352	5.0	112	464
Alfalfa	1283	18.0	409	1692
Sudan	70	1.0	23	93
Mixed Pasture	120	1.7	39	159
Almonds	94	1.3	30	124
Totals	7115	100	2271	9386

* 7115 acres for disposal of wastes from 47 dairies is an average of 151 acres per dairy. For the 15 dairies not surveyed this is an additional 2271 acres used for dairy waste disposal. Estimates of the additional acreages receiving dairy wastes for the individual crop types are based on the percentages observed for the 47 dairies which were surveyed.

Table 16. Acres of Crops Fertilized with Poultry Wastes

Crop	Acres
Almonds	361
Corn	247
Vineyards	247
Total	855

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Table 17. Hilmar Crop Acreages and Nitrogen and Salt Contributions from Commercial Fertilizers

Crop	Total Crop Acres	Acres Fertilized with Animal Wastes	Acres Fertilized with Commercial Fertilizers	Applied Nitrogen ² from Commercial Fertilizers (lbs N/yr)	Applied Salts ³ from Commercial Fertilizers (lbs salt/yr)
Corn	4904	3865	1039	207,800	1,015,103
Corn (grain) ⁴	3700	3700	0	0	0
Almonds	4823	485	4338	650,700	3,153,726
Alfalfa	1945	1692	253	7,590	69,069
Mixed Pasture	981	159	822	45,210	215,364
Vineyards	936	247	689	34,450	115,063
Grains	491	0	491	31,915	175,778
Walnuts	460	0	460	69,000	334,420
Sweet Potatoes	417	0	417	41,700	199,326
Lawn	161	0	161	32,200	177,261
Sudan	158	93	65	3,900	22,295
Beans (dry)	154	0	154	4,620	32,500
Peaches, Nectarines	105	0	105	15,750	76,335
Melons, Squash, Cucumbers	75	0	75	7,500	35,250
Native Pasture	32	0	32	1,760	8,324
Total	19,342	10,241	9,101	1,154,095	5,636,474

¹ Crop acres determined from the DWR 1980 land use map.

² Applied nitrogen is based on recommended fertilizer application rates given in Table 13.

³ Applied salts is based on commercial fertilizer salt contributions listed in Table 13.

⁴ Corn (grain) represents double-cropping; summer corn is followed by fall grain.

Note: The number of acres of corn (grain) on the 1980 land use map is less than that indicated by the animal waste surveys, to be fertilized with animal wastes. 6,854 acres of corn (grain) were fertilized with animal wastes. Since only 3700 such acres are shown on the land use map, the excess 3,154 acres are included as corn acres.

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Table 18.

HILMAR GROUNDWATER STUDY - WELL DATA

WELL NUMBER	TOTAL WELL DEPTH (FT)	CASING WELL DEPTH (FT)	PERFORATION INTERVAL (FT)	AQUIFER*	CASING DIAMETER (IN)	WELL USE**	WELL LOG	DEPTH OF SURFACE SEAL 10 (FT)	
5S 10E 36H1	190	175	155-175	C	6	H	YES	50	bentonite
5S 10E 36H2	305	300	240-300	C	8	H,D	YES	50	?
6S 10E 02A1	?	65	45-65	U	6	H	NO	?	
6S 10E 02A2	?	?	?	?	?	H	NO	?	
6S 10E 02J1	?	110?	?	U?	?	H	NO	?	
6S 10E 2J2	125	100	?	U	8	H	NO	?	
6S 10E 2K1	202	190	175-190	C	6	H	YES	20	bentonite
6S 10E 02A	160	132	0-132	U	18	DW	YES	?	
6S 10E 03H1	200	200	?	C	16	I	YES	none	
6S 10E 03H2	100	97	77-97	U	6	D	YES	50	cement
6S 10E 03N	?	180?	?	U?	8	PD	NO	?	
6S 10E 03P	?	?	?	?	6	H?	NO	?	
6S 10E 04J	262	225	?	C	6	H,D	YES	115	cement
6S 10E 04N1	79	77	?	U	7	H	NO	?	
6S 10E 04N2	?	30	?	U	6	H	NO	?	
6S 10E 04Q	?	40	?	U	?	PD	NO	?	
6S 10E 04R1	?	180X	?	C?	?	H	NO	?	
6S 10E 04R2	170	170	?	U	16	I	YES	?	
6S 10E 04R3	?	?	?	?	?	PD	NO	?	
6S 10E 05C	248	237	0-237	C	16-14	DW	YES	none	
6S 10E 05J	115	115	95-115	U	6	H	YES	50	cement
6S 10E 05P	97	82	67-82	U	8	H,D	YES	50	bentonite
6S 10E 05R	230	?	10-155	U	16-12	DW	YES	?	
6S 10E 08F+	138	110	80-110	U	8	H,D	YES	50	bentonite
	170	110	95-110	U	8	H,D	YES	50	?
6S 10E 08G	?	40	?	U	?	H?	NO	?	
6S 10E 08H1	84	80	60-80	U	8	H,D	YES	50	?
6S 10E 08H2	242	160	0-105	U	24-14	DW	YES	?	
6S 10E 09J	110	70	60-70	U	6 5/8	H	YES	none	
6S 10E 10G	277	190	170-190	C	8	H,D	YES	none	
6S 10E 10N	95	80	60-80	U	6	H	YES	20	bentonite
6S 10E 10Q	?	30	?	U	?	H	NO	?	
6S 10E 11A2	?	28	?	U	6	H	NO	?	
6S 10E 11A3	?	85	?	U	6	H	NO	?	
6S 10E 11B	?	40?	?	U?	6	?	NO	?	
6S 10E 11G	?	80	?	U	16	I	NO	?	
6S 10E 11N	350	291	0-291	C	18	DW	YES	none	
6S 10E 14F	?	104	?	U	16	DW	YES	?	
6S 10E 14Q	?	96	?	U	16	DW,X	YES	none	
6S 10E 14R	128	125	85-125	U	8	P	YES	50	cement
6S 10E 15B1	?	70	?	U	8	D	NO	?	
6S 10E 15B2	95	95	75-95	U	6	H	YES	50	bentonite
6S 10E 15F	?	136	0-136	U	18	DW,X	YES	?	
6S 10E 16E1	100	68	58-68	U	6	H,D	YES	none	
6S 10E 16K1	?	20?	?	U?	?	H	NO	none	

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HILMAR GROUNDWATER STUDY - WELL DATA

WELL NUMBER	TOTAL WELL DEPTH (FT)	CASING WELL DEPTH (FT)	PERFORATION INTERVAL (FT)	AQUIFER*	CASING DIAMETER (IN)	WELL USE**	WELL LOG
→ 6S 10E 168X L2	?	?	?	?	7	H	NO ?
6S 10E 16P1	130	129	104-116 121-129	U	8	H,D	YES 50 Cement
6S 10E 16P2	?	95	?	U	8	H,D	NO ?
6S 10E 17J	200	200	?	U	8	H	YES none
6S 10E 17Q	172	160	140-160	U	6	H	YES 110 Cement
6S 10E 20A	127	126	114-126	U	6	H	YES 20 bentonite
6S 10E 21E1	81	64	?	U	?	H,D	NO ?
6S 10E 21F2	?	131	20-80	U	16	DW,I	YES ?
→ 6S 10E 21HX3	?	?	?	?	6	H	NO ?
→ 6S 10E 21HX1	96	80	70-80	U	6 5/8	H	YES none
→ 6S 10E 21HX2	104	102	28-102	U	18	DW,X	YES ?
6S 10E 22M	115	100	80-100	U	6	H	YES 20 bentonite
6S 10E 23P	?	96	0-96	U	24-16	DW,X	YES ?
6S 10E 24L	97	95	85-95	U	8	H	YES 20 bentonite
6S 10E 26G	?	50	?	U	6	H,D	NO ?
6S 10E 26K	?	196X	?	UX	6	H	NO ?
6S 10E 26L	100	93	73-93	U	6	H	YES 20 ?
6S 10E 26Q	?	70	?	U	6	H?	NO ?
6S 10E 27L1	?	120?	?	U?	8	H,D	NO 29 Cement
6S 10E 27L2	65	64	44-64	U	8	H,D?	YES 11012
6S 10E 29A	158	133	113-133	U	8	H,D	YES 50 bentonite
6S 10E 32C	115	80	60-80	U	6	H	YES 20 bentonite
6S 10E 33H	?	100	?	U	7	H	NO none
6S 11E 18E	?	120	44-96	U	16	DW,X	YES ?
6S 11E 19C	140	115	50-115	U	14	I	YES none
6S 11E 30C	?	100	50-100	U	6	H,I	NO ?

+ water from two wells

AQUIFER*
U=upper,unconfined
C=lower,confined

WELL USE**
D=dairy
PD=previous dairy
H=domestic
I=irrigation,
P=poultry
DW=drainage well